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German Standard Problem 4a

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Prepared by W. B. Walton, G. H. Howard, B. Johnson

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ABSTRACT

This study deals with structural piping response to dynamic loads generated by hydraulic transients in nuclear power plants. Transients were induced by means of a rupture disc and closure of a feedwater check valve at the Heissdampfreaktor, West Germany. Blind predictions of piping response were made using the computer code EASE2. Comparisons between computer simulations and experimental observations are contained in the report.

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PREFACE

The following study was conducted by ANCO Engineers, Inc. for the Division of Reactor Safety Research (Dr. John O'Brien, Project Officer), Nuclear Regulatory Commission as part of a joint research effort supported by the NRC and the Ministry of the Interior (BMI) of the Federal Republic of Germany. This report is one of a series of studies conducted by ANCO Engineers as part of the Heissdampfreaktor safety research program. Primary responsibility at ANCO for the work reported herein rests with Mr. William B. Walton, Dr. George H. Howard, and Mr. Blake Johnson. The authors gratefully acknowledge the support provided by Dr. W. Winkler and Dr. T. Grillenberger of Gesellschaft fur Reaktorsiecherheit, Garshing, as well as Dr. L. Malcher and Dr. Katzenmeier of Kernforschungszentrum Karlsruhe.

1.0 INTRODUCTION

At the request of the Ministry of the Interior (BMI) Federal Republic of Germany, the Society for Reactor Safety (GRS) formulated suggestions dealing with, among other things, the formulation and execution of a Standard Problem in the area of pressure wave propagation in nuclear power plant piping systems. Ultimately, German Standard Problem No. 4 (DSP4) was defined and funded. The aim of this problem was to study the closing behavior of a feedwater check valve and the fluid dynamics in its respective pipeline as a result of a simualted break in the pipeline and ensuing rapid closure of the check valve. The tests were to be performed at the Heissdampfreaktor (HDR) using the URL pipe system.

In connection with this study an additional German Standard Problem (4a) was defined. This study was to be a part of the same tests performed for problem 4. The emphasis here would be the determination of the structural dynamic behavior of the pipe system (measurement and calcualtion of pipe displacements, accelerations, strains/stresses) when subjected to fluid forces from the problem 4 event.

As a part of German Standard Problem 4a (DSP4a), ten (10) engineering firms performed "blind" calculations to predict the structural dynamic response of the URL piping system to problem 4 fluid forces. The results of these calculations were sent via magnetic tape to GRS prior to distribution by GRS of the embargoed experimental results. Chapter 6 of this report presents a very brief comparison of ANCO's predictions to the subsequently released data. ANCO Engineers, Inc. was one of those firms and the sole American participant. This report documents the tasks performed in predicting the URL response.

2.0 DESCRIPTION OF GERMAN STANDARD PROBLEM 4a (DSP4a)

DSP4 was an experimental and theoretical simulation of an assumed break in a feedwater line for a nuclear power plant. The simulation was performed using a leg (portion) of the modified recirculating loop of the Heissdampfreaktor (HDR) at Kahl, West Germany (see Figure 2.1). The pipe system was modified by rebuilding a portion of the external forced circulation loop. This involved installing circulation pump Z 199 (Item 7 in Figure 2.1).

The test involved circulating compressed water* through a portion of the pipe system. The circulation started from the S-support 3 (see Figure 2.1) and travelled to a spherical piece 12, and on through locations 6, 7, 5, 11, 10, 4, 9, and back to the reactor vessel 2. Once steady-state fluid conditions were achieved, the break in the feedwater line was simulated. This involved: (1) circulation pump shut off; (2) fracture of the rupture disc (8 in Figure 2.1, simulated assumed break); (3) closing of rapid shutoff valve 5; and (4) eventual closure of the check-valve 4. At check-valve closure, pressure waves were generated which propogated through the system.

The pressure waves generated during the test were of such amplitude that a high stress state in the pipe material resulted (high relative to the yield stress of the material). For this reason it was of importance to understand the structural dynamic behavior of the pipe system during the fluid dynamic event. This is where DSP4a ties in with DSP4. For DSP4a, the structural dynamic behavior of the URL test pipe line was to be theoretically determined; applied structural loading was to be determined from the

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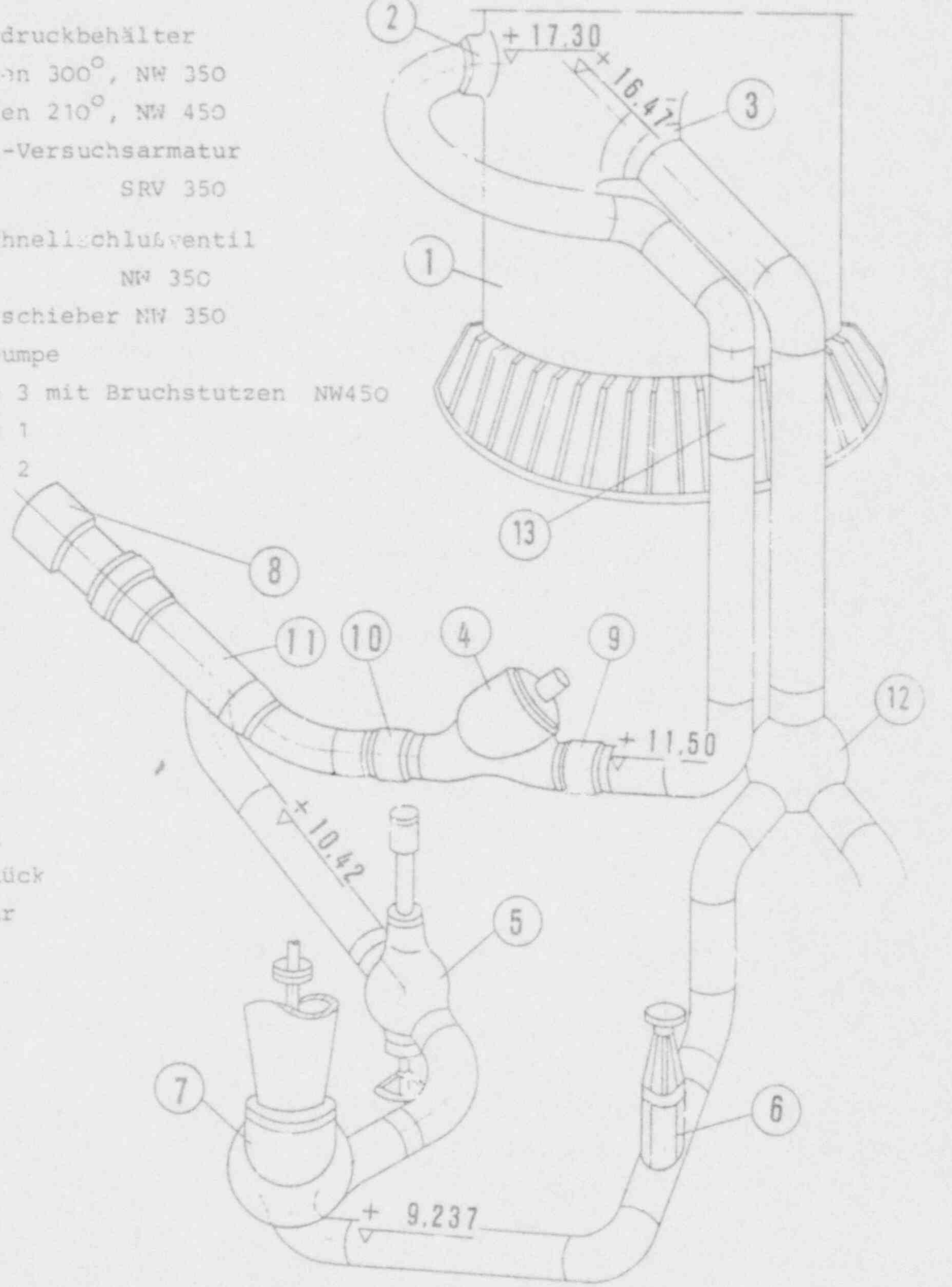
*Note: The state of the water in the test line during the circulation phase was 70 bar (1015 psi), 220°C (428°F), and 4 m/sec (13.1 ft/sec; in opposite direction to blowdown flow direction).

FIGURE 2.1: MODIFIED PRIMARY COOLANT LOOP AT HDR

Legende

① Reaktordruckbehälter
② T-Stutzen 300°, NW 350
③ S-Stutzen 210°, NW 450
④ Sempell-Versuchsarmatur SRV 350
⑤ Allo-Schnellschlußventil NW 350
⑥ Absperrschieber NW 350
⑦ Umwälzpumpe
⑧ Meßring 3 mit Bruchstutzen NW450
⑨ Meßring 1
⑩ Meßring 2
⑪ T-Stück
⑫ Kugelstück
⑬ Testrohr



DSP4 test data.* During the blowdown test the URL pipe was instrumented with displacement transducers, accelerometers, and strain gauges. The data from these instruments is the basis against which all DSP4a theoretical simulation results are to be compared.

The portion of the URL system involved in the structural simulation is shown in Figure 2.2. The pipe has a total length of 18.80 meters (61.68 ft). The pipe begins at the reactor vessel and travels to a rupture disk at its other end. There is a fixed point near the rupture disk. There are no structural supports (snubbers or struts) attached to the pipe. The dimensions and material specification of the various sections of the pipe are given in Table 2.1. The inner pipe diameter and wall thickness vary from 0.351 to 0.453 meter (1.152 to 1.486 ft) and 0.014 to 0.142 meter (0.046 to 0.466 ft), respectively.

As a part of the theoretical simulation for DSP4a, the specified response quantities are to be calculated; they are displacement, acceleration, and stress. The components of stress of interest are the bending, tensile, torsional, tangential, and comparative (von Mises) stresses. Also, the bending axis angle was desired. Figure 2.3 and Table 2.2 describe the desired quantities.

The fluid forces on the pipe, due to the pressure waves, were to be calculated using the DSP4 test data (i.e., fluid pressure). The pressure as a function of time is known at numerous locations, particularly at inlets and/or outlets of pipe elbows. The method used for obtaining the forces was to be developed by each investigator. Thus, DSP4a involves determining both the fluid/structure interface forces and the structural response.

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*Note: The calculations performed by ANCO Engineers, Inc. were to simulate reality as closely as possible (they were not designed to be conservative). Also, no previous (prior to completion of the analysis) knowledge of the structural dynamic test results was known.

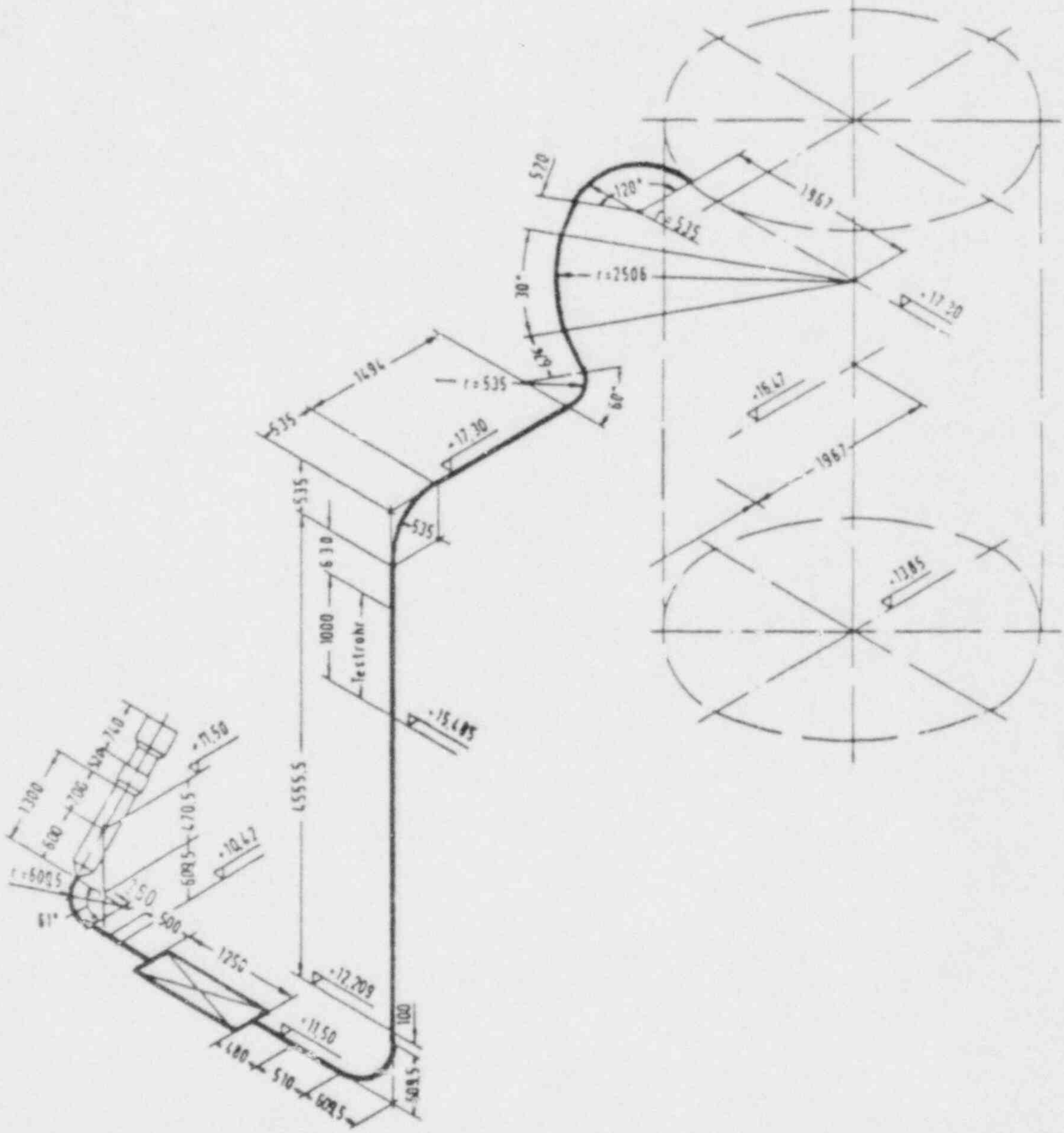


FIGURE 2.2: Portion of URL System Used for Structural Dynamic Simulation.

TABLE 2.1

DIMENSIONS AND MATERIAL DESIGNATIONS FOR PIPE SECTIONS

Lfd.* Nr.	Teilstück	Werkstoff	Nennweite	Innendurchmesser [mm]	mittlere x) Wanddicke [mm]	Teilstück-länge [mm]
1	RDB-Wand	23NiMoCr36	-	-	142	142
2	T-Stutzen	23NiMoCr36	NW 350	351,2	104,4/27,6	375
3	120°-Bogen	Nr. 4550	NW 350	360	25,0	1120
4	Rohrstück mit 30°-Biegung	Nr. 4550	NW 350	360	19,3	2508
5	60°-Bogen	Nr. 4550	NW 350	360	25,0	560
6	Rohrstück	Nr. 4550	NW 350	360	19,3	1494
7	90°-Bogen	Nr. 4550	NW 350	360	25,0	840
8	Rohrstück	Nr. 4550	NW 350	360	19,3	630
9	Probenstück	WB 35	NW 350	377	14,0	1000
10	Rohrstück	Nr. 4550	NW 350	360	19,3	2925
11	Übergangsstück	15Mo3	NW 350	360	19,3/25,0	100
12	90°-Bogen	15Mo3	NW 350	356,4	25,0	957
13	Rohrstück	15Mo3	NW 350	371,4	17,5	510
14	Meßring I	15Mo3	-	371,4	-	480
15	SRV 350	GS C25	NW 350	-	-	1250
16	Meßring II	15Mo3	-	371,4	-	500
17	Rohrstück	15Mo3	NW 350	371,4	17,5	260
18	61°-Bogen	15Mo3	NW 350	356,4	25,0	648
19	T-Stück	15Mo3	NW450/350	428/371,4	40,0/17,5	1300
20	Stutzen	15Mo3	NW 450	453	61,0	520
21	Meßring III m. Bruchstutzen	15Mo3	NW 450	453	27,5/93,5	740
22	Berstscheiben u. Mündungsrohr		NW 450	453	-	250
						19109

x) Die mittlere Wanddicke wurde aus den Angaben der Rohrleitungszeichnungen entnommen und weicht erheblich von den an einzelnen Stellen durchgeführten MPA-Messungen ab (siehe Anlage 12).
Die beim Probenstück (lfd. Nr. 9) angegebenen Maße sind Istmaße.

* Note: These sections are defined in the next page of this table.

TABLE 2.1 (Continued)

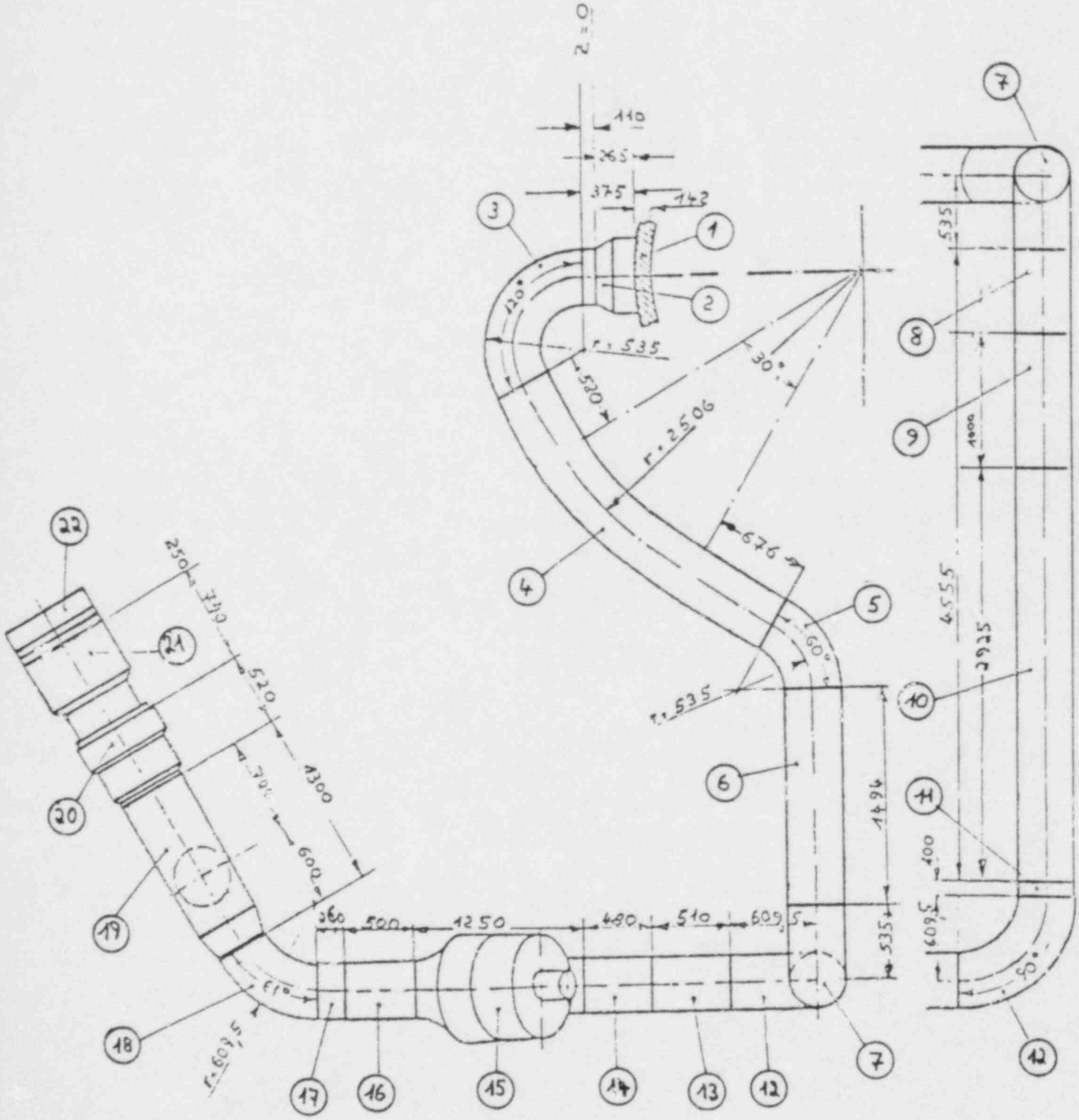


FIGURE 2.3: Desired Structural Response Quantities.

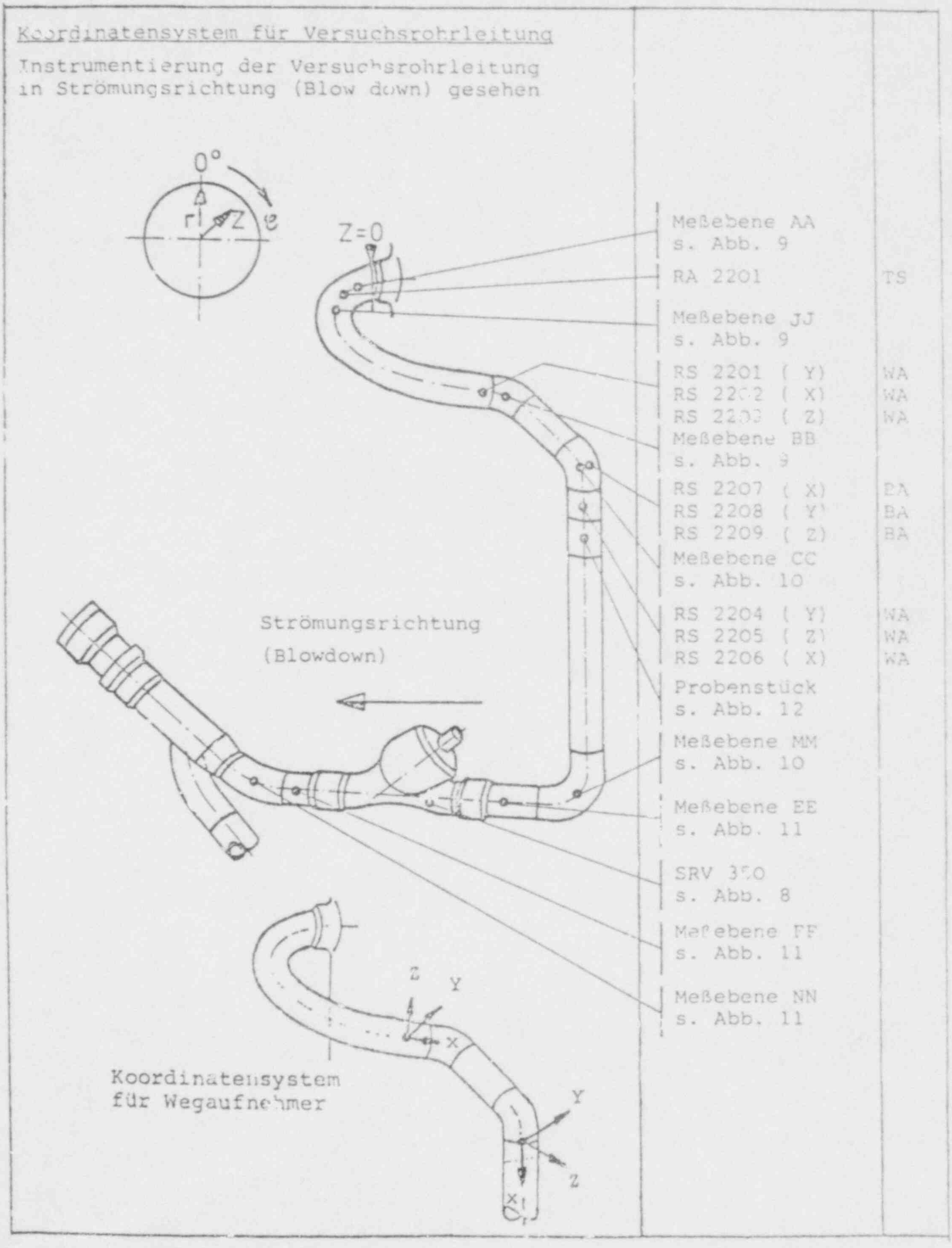


TABLE 2.2: DESIRED STRUCTURAL RESPONSE QUANTITIES

Entsprechende Meßstelle	zu ermittelnde Größe	
RS 2201	Weg in y-Richtung	(3,4 m vom RDB-Stutzen)
RS 2202	Weg in x-Richtung	
RS 2203	Weg in z-Richtung	
RS 2204	Weg in y-Richtung	(7,7 m vom RDB-Stutzen)
RS 2205	Weg in z-Richtung	
RS 2206	Weg in x-Richtung	
SS 4004	Weg in z-Richtung	am Ventil
SS 4005	Weg in x-Richtung	
SS 4006	Weg in y-Richtung	
SS 4001	Beschleunigung in x-Richtung	am Ventil
SS 4002	Beschleunigung in y-Richtung	
SS 4003	Beschleunigung in z-Richtung	
RK 1010	Zugspannung	Meßebene A
RK 2010	Biegespannung	
RK 2210	Winkel der Biegeachse	
RK 3010	Torsionsspannung	
RK 4110	Tangentialspannung durch Innendruck	
RK 5010	Vergleichsspannung	
RK 1011	Zugspannung	Meßebene C1
RK 2011	Biegespannung	
RK 2211	Winkel der Biegeachse	
RK 3011	Torsionsspannung	
RK 4111	Tangentialspannung durch Innendruck	
RK 5011	Vergleichsspannung	
RK 1012	Zugspannung	Meßebene M1
RK 2012	Biegespannung	
RK 2212	Winkel der Biegeachse	
RK 3012	Torsionsspannung	
RK 4112	Tangentialspannung durch Innendruck	
RK 5012	Vergleichsspannung	
RK 1013	Zugspannung	Meßebene E
RK 2013	Biegespannung	
RK 2213	Winkel der Biegeachse	
RK 3013	Torsionsspannung	
RK 4113	Tangentialspannung durch Innendruck	
RK 5013	Vergleichsspannung	
RK 1014	Zugspannung	Meßebene F
RK 2014	Biegespannung	
RK 2214	Winkel der Biegeachse	
RK 3014	Torsionsspannung	
RK 4114	Tangentialspannung durch Innendruck	
RK 5014	Vergleichsspannung	

3.0 STRUCTURAL MODEL OF THE URL PIPE SYSTEM

To simulate the dynamic behavior of the URL pipe structure for DSP4a, a linear finite element model was constructed.* A plot representing the model is shown in Figure 3.1. The model includes the section of the pipe from the reactor vessel wall to the T-piece. Fixed points (all degrees of freedom deleted) were assumed at each end of the pipe. The model was defined using 30 nodes (end nodes fixed; 168 degrees of freedom) and 27 finite elements (straight and curved pipe elements). Appendix A contains a partial listing of the EASE2 input data deck which defines the finite element model.

Various coordinate systems were defined. The global coordinate system (the reference system for mass and stiffness matrix assembly) is given by X, Y, Z (see Figure 3.1). Local coordinate systems were defined for output of displacement and acceleration simulation results in accordance with DSP4a definition (specified by the Society for Reactor Safety; T. Grillenberger); they are shown in Figure 3.2 and are represented by x, y, z.

A flexibility factor k_p is used in EASE2 to modify the bending terms in the flexibility matrix for the curved pipe element. The flexibility matrix for the curved pipe element is derived totally from curved beam theory. This overestimates the stiffness (as compared to experimental data). To correct for this, the flexibility factor k_p is used. It is given by:

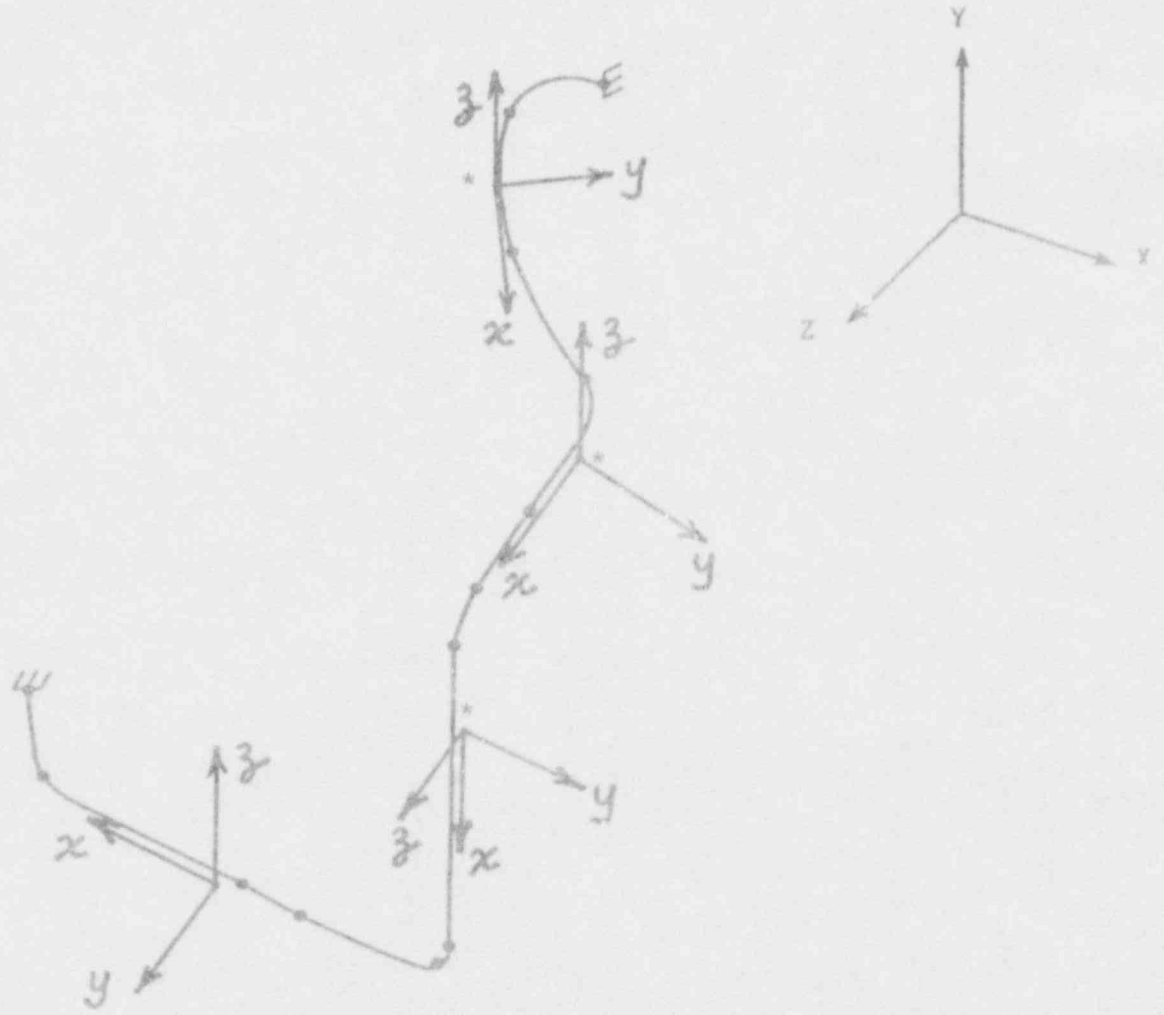
$$k_p = (1.65/h)/[1 + (6p/Eh)(R/t)^{4/3}] \geq 1$$

---

*Note: The computer code EASE2 (Elastic Analysis for Structural Engineering) was used. This code is accessible through the CDC Cybernet Network Worldwide.

FIGURE 3.1: ANCO EASE2 Structural Model (Partial List of Node Numbers).

FIGURE 3.2: Local Coordinate Systems.*



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* Note: These coordinate systems are for output of displacements and acclerations.

where: p = internal pressure
h = tR/r^2
r = $(d_o-t)/2$
R = bend radius
t = wall thickness
d_o = outside pipe diameter
E = Young's modulus

This correction can be significant. From experience, errors on the order of 25% have been observed in the first natural frequency of piping systems when this correction was not included.

Following model formulation, an eigenvalue analysis of the URL model was executed. The first ten (10) eigenfrequencies are given in Table 3.1. It is likely that with the number of nodes used in defining the pipe model (30 nodes) that the last few modes are not accurately defined. If it is minimally acceptable to use four points to define a half cycle of a standing wave, then the seventh (7th) mode is approximately the highest mode that can be acceptably defined with the thirty (30) node points. Four points will reasonably well define a half cycle. For three points, it is possible to define up to about the tenth (10th) mode. Three points will marginally define a half cycle. For these reasons, it is reasonable to expect the URL modes to be fairly well defined up to at least the eight (8th) or ninth (9th) mode.

TABLE 3.1

NATURAL FREQUENCIES FOR HDR/URL BLOWDOWN MODEL

Mode #	Eigenfrequency (Hz)
1	5.46
2	8.54
3	9.43
4	26.18
5	30.55
6	39.71
7	45.57
8	50.54
9	64.23
10	76.22

4.0 PRESSURE WAVE FORCES ON THE URL PIPE

DSP4a involves accurately simulating the structural dynamic response of the modified URL system when excited by the DSP4 blowdown fluid forces. This type of simulation deals with fluid-structure interaction (the response of a structure due to transient fluid events).

There are two general approaches to the fluid-structure problem. One involves the difinition and solution of a coupled problem. For this approach, the equations representing the fluid and structure behavior are coupled to each other. In order to solve for the response of either the fluid or structure, the response of both must be found simultaneously. The other approach involves determining an uncoupled solution. This involves solving for or determining experimentally the fluid response, independently of the structural response. The fluid response is then input into the structural problem, and the uncoupled structural response is determined. The latter of these two approaches was used for DSP4a. This is because the fluid response, determined as a part of DSP4, is to be used as input to DSP4a. The fluid response (i.e., pressure) is to be used to determine the fluid forces on the URL pipe. These forces will be used in determining the structural response.

Given the transient fluid response of a system, there are at least two possible basic approaches for determining the fluid forces (uncoupled fluid-structural problem) on a pipe system. One approach could be called the "equivalent concentrated forces method." Basically it says, given a continuous fluid stress distribution in a pipe (at the pipe fluid interface), it is possible to determine equivalent concentrated loads at the node points used to define the structural model. This is done, in part, by applying the following equation:

$$P_{eq} = \int_s a^T \phi dS$$

where P_{eq} is the equivalent end load vector for a pipe element, a^T is the transpose of the matrix a, where a gives the relationship, for a discrete structural element (i.e., finite element), between the spatially continuous interior displacements and the discrete element displacements (at the node points), ϕ is the matrix of distributed surface stresses (distributed field of fluid stress), and dS refers to the integration being carried out over the applicable surface (s). This expression is only for a single element. A P_{eq} would have to be determined for each element. Then, a global P_{eq} would need to be determined for the entire structure. This is an excellent approach, provided the distributed loading can be determined for the entire structure. This may be possible for the DSP4a, but would be very difficult, if at all possible. As this is a wave propagation problem, it greatly complicates the determination of a continuous pressure distribution. Because of this, it was decided to use a second approach to solving the uncoupled problem.

Another of the basic uncoupled fluid-structure approaches involves the use of the linear momentum equation from fluid mechanics (control volume formulation):

$$\overline{F}_s + \iiint_{C.V.} \overline{B}(\rho dv) = \iint_{C.S.} \overline{V}(\rho\overline{V}\cdot d\overline{A}) + \frac{\partial}{\partial t}\iiint_{C.V.} \overline{V}(\rho dv)$$

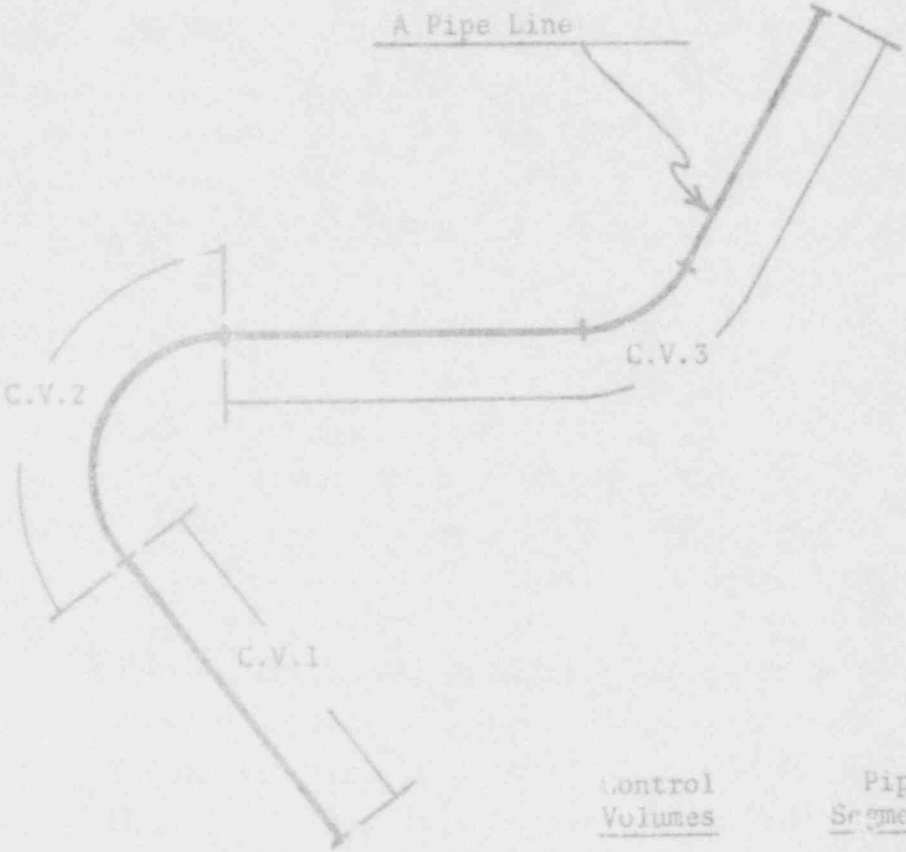
where $\overline{F}_s$ is the total surface force on the control surface (C.S.), $\overline{B}$ is the body force distribution, $\overline{V}$ is the fluid velocity, $d\overline{A}$ is a differential area normal to the C.S. and ρ is the fluid density.

To apply this equation, the space occupied by the fluid in the pipe was subdivided into control volumes (the union of the control volumes is equal to the total space in the pipe). There are an infinite number of ways to subdivide the space. Various methods for doing this have been devised.

The control volumes for this problem obviously had to be contained in straight, curved, and combinations of straight and curved lengths of pipe (see Figure 4.1). One constraint on the selection of volumes was that the pressure had to be known at each of its two ends. (As will be discussed later, this was not necessary for straight volumes.) This is necessary for evaluating the surface force $\overline{F}_s$.

The question arises as to how large the control volumes can be (or to how small they should be). For each control volume, there is essentially one resultant force. If there are only a few control volumes, there will only be a few forces representing the spatially continuous load distribution on the pipe. The smaller the control volumes the more closely their combined loading resembles the continuous loading.

In choosing the size of a control volume it is important to consider the degree to which the center of pressure of its respective fluid changes location during the fluid dynamic event. The control volume resultant force should be applied at the center of pressure. This can be done by having a fine mesh for the discrete structural model, especially for such elements as curved pipes (locations where some of the largest resultant forces are generated). During the structural simulation the resultant force can be moved from node to node. Even though these calculations can be performed with enough data, they are very involved (i.e., the center of pressure must be calculated at each solution step). This, coupled together with the fact that only a relatively limited amount of DSP4 data is available, the resultant control volume force, for DSP4a, was not applied at the center of pressure, but approximately at the geometric center of the control volume. If the control volumes are chosen to be too large there will possibly be considerable error in the force application point locations.



Control Volumes	Pipe Segments
C.V.1	Straight
C.V.2	Curved
C.V.3	Straight/Curved

FIGURE 4.1: Some Possible Combinations of Pipe Segments Used in Defining Control Volumes.

On the basis of the above discussion, the URL blowdown model (DSP4a) was broken up into six (6) control volumes (see Figure 4.2). As can be seen, four of the volumes are made up of a combination of straight and curved sections. Two of the volumes are straight. The point of application of the resultant force for a given control volume is represented by the designator LP (load point). No load point is defined for volume six (6). This volume is straight with the only forces it can exert on its section of pipe being frictional. For a DSP4 type of event, the frictional fluid forces are negligible.

In determining the control volume forces on the pipe, it is necessary to evaluate the momentum efflux rate, rate of change of control volume momentum, and body force integrals for each control volume. The two momentum integrals are dependent on mass flow rates. The major events that take place during the DSP4 test that might effect the mass flow rate are: (1) the circulation pump gives a constant flow rate of compressed liquid of approximately 1600 m^3/hour (15.7 ft /sec); (2) the pump is shut off at the beginning of the test, resulting in essentially zero flow rate; (3) fracture of the rupture disc, resulting in flashing of the compressed liquid at the disc; (4) closing of the rapid shut-off valve immediately after ruputure disc fracture (this insures isolation of the second section of pipe); and (5) closing of the check-valve SRV350, resulting in zero mass flow rate between the fitting and reactor vessel (after closure). The flashing will give rise to large steam and small to moderate compressed liquid velocities. This will generate some force on the pipe, but is not the major forcing generated during the entire event. The major forcing is generated during check-valve closure. For this phase of the forcing, the compressed liquid flow rate is initially at a small to moderate level. As the event progresses, the flow rate will diminish, eventually, to zero. Figure 4.3 gives a hypothetical example of this. With the portion of the DSP4 event that gives rise to the largest forcing, seeing only from moderate to zero net flow rates, a reasonable assumption for calculating peak forces on the URL pipe may be that the fluid flow terms in the momentum equation can be neglected. Also, it is reasonable to assume that the body force distribution will not materially affect the flow.

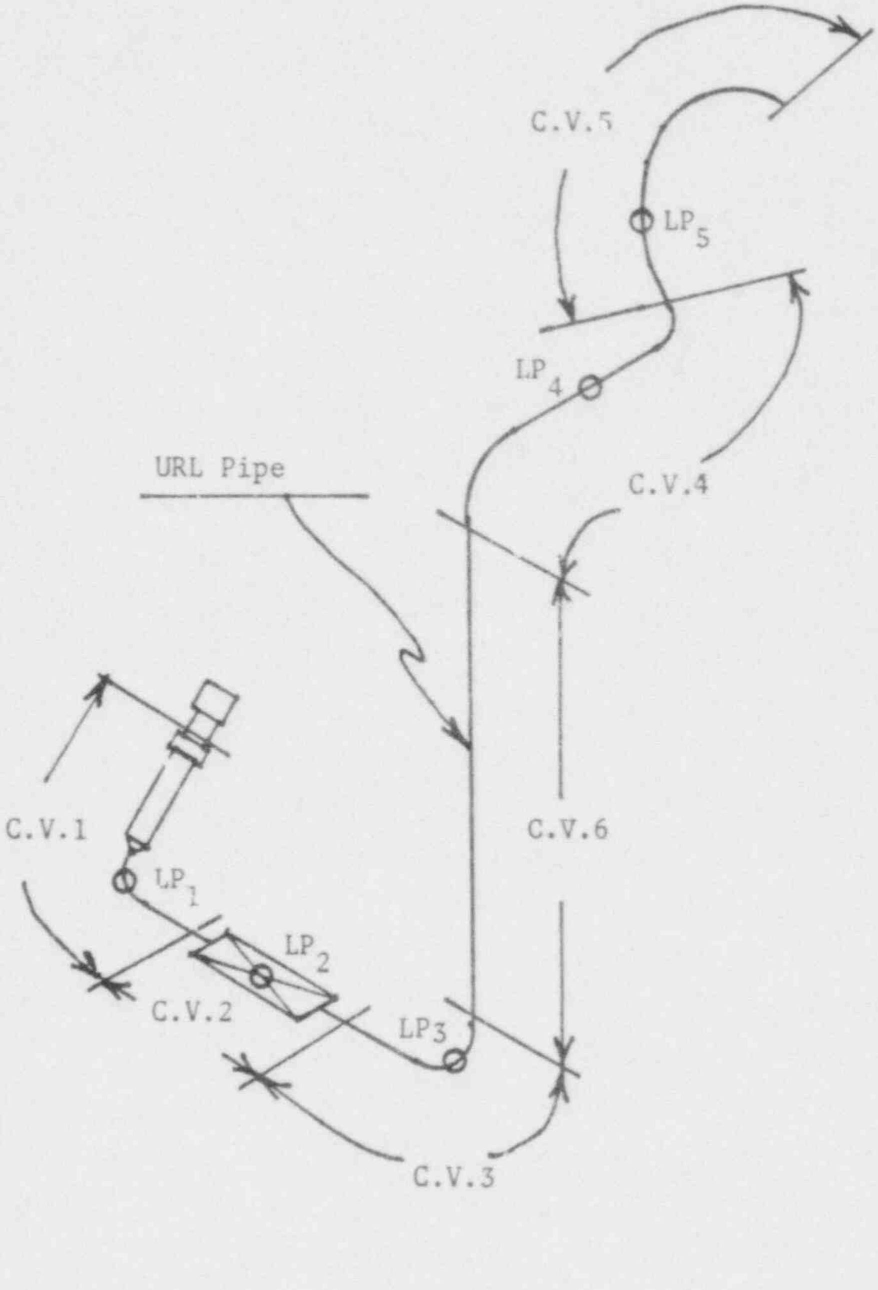
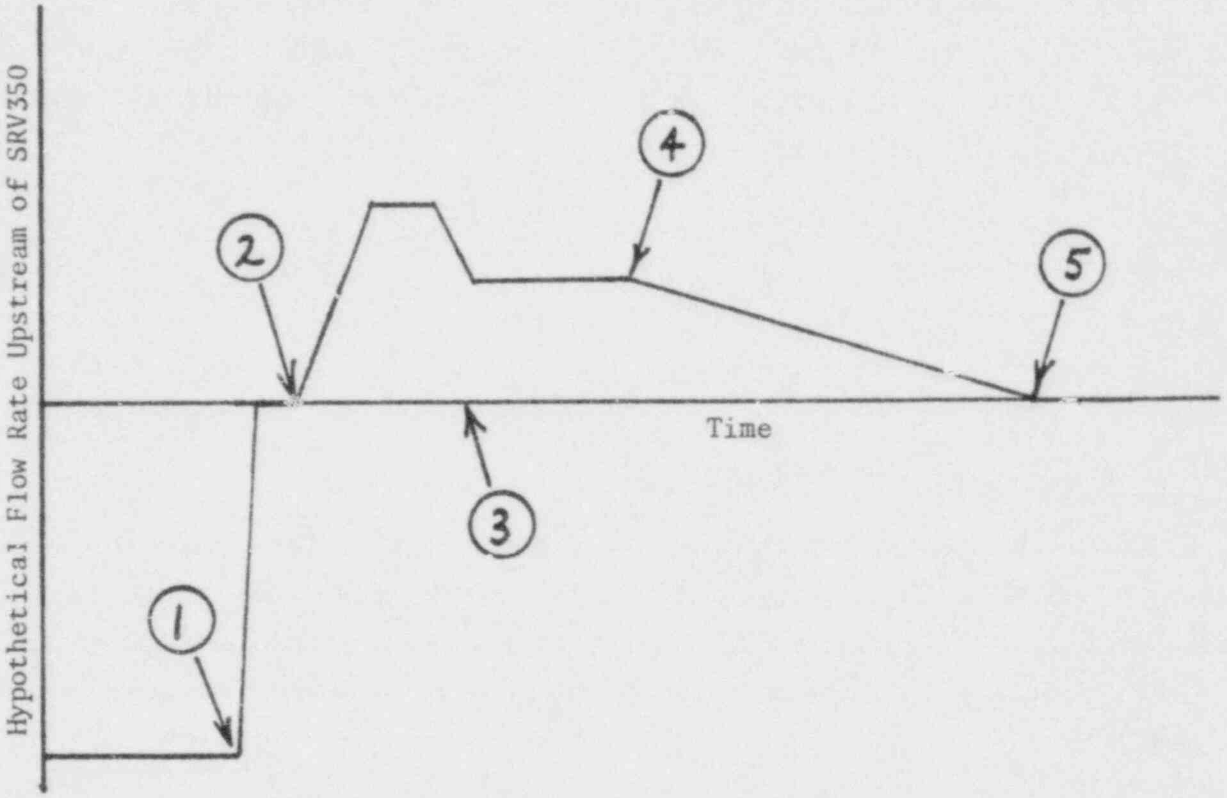


FIGURE 4.2. Control Volumes Used for DSP4a.



Sequence of Events	Description
1	Circulation pump shut off
2	Fracture of bursting disc
3	Closing of rapid shutoff valve
4	SRV350 begins to close
5	Closure of SRV350

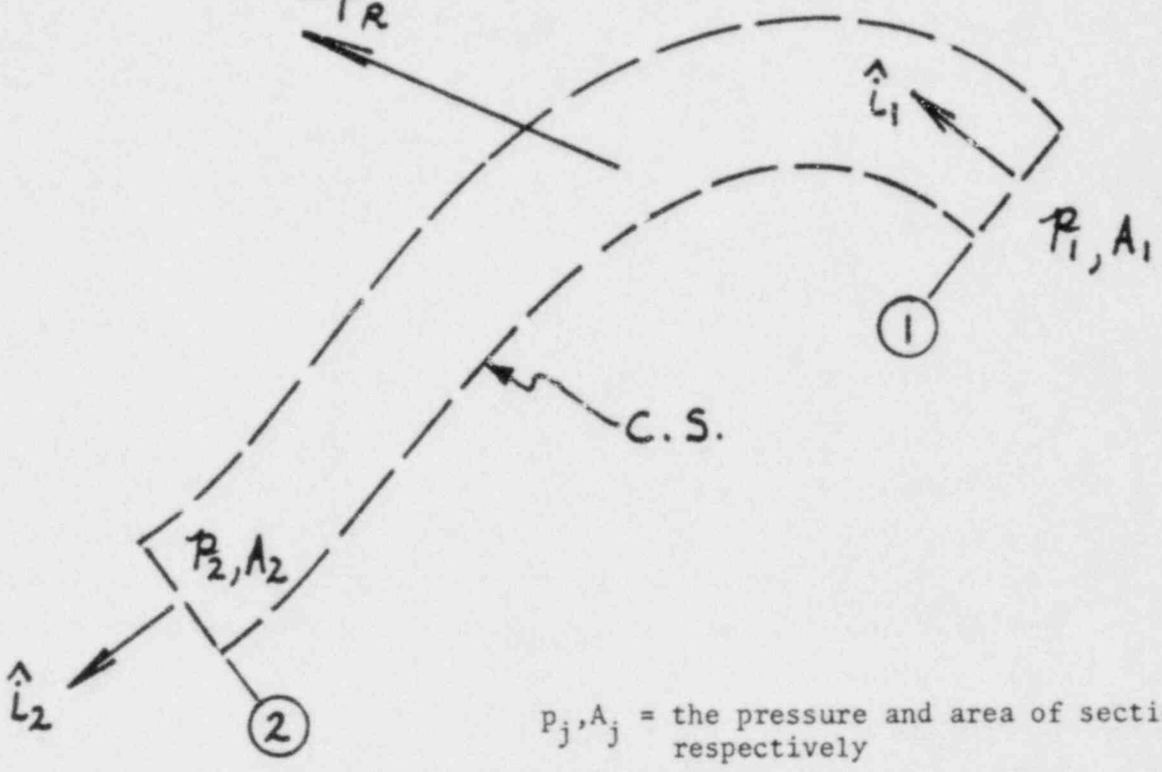
FIGURE 4.3: Hypothetical Example of A DSP4 Event.

Using these assumptions, the momentum equation (control volume formulation) reduces to $\overline{F}_s = 0$ (the sum of the external surface forces equals zero). This equation is applied to an arbitrarily shaped control volume (for a piping system) as shown in Figure 4.4. The only forces of concern are the pressure forces (forces on the control volume from the adjacent fluid) and the force of the pipe on the volume. It is seen that the resultant force of a control volume (using the above assumptions) on its corresponding section of pipe is given by:

$$\overline{F}_R = p_1 A_1 \hat{i}_1 - p_2 A_2 \hat{i}_2$$

This equation is applied to each of the control volumes used to define the URL space. Figure 4.5 defines the pressures and area used in the computations. The equations for the fluid forces (on the pipe) at the load points are given in Table 4.1. Appendix B gives the derivation of these simple equations.

The fluid pressure time history data was used together with the equations in Table 4.1 to calculate the fluid forces on the pipe. The channels of pressure data that were taken to correspond to P_1 ,..., P_7 are listed in Table 4.2. Plots of the calculated fluid forces on the pipe are given in Figures 4.6 through 4.15. Table 4.3 gives the force application point and direction for a given force number (i.e., force number RF0006). Table 4.4 gives the minimum and maximum values of each of the force components.



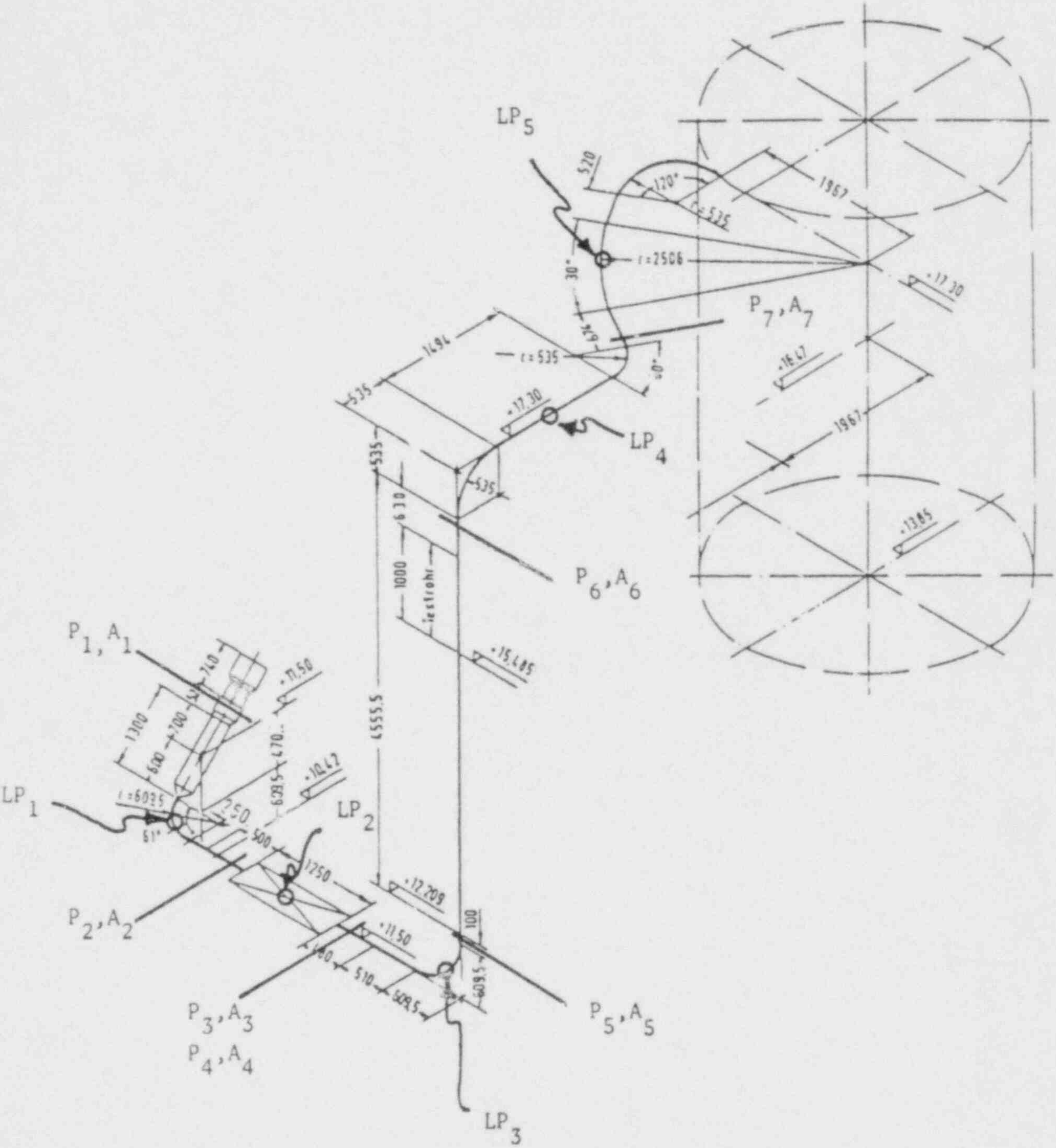
p_j, A_j = the pressure and area of section j, respectively

$\hat{i}_j$ = the tangent unit vector at section j

$\overline{F}_R$ = resultant force of the control volume on the pipe

FIGURE 4.4: Arbitrarily Shaped Control Volume for Obtaining Pipe Segment Forces.

FIGURE 4.5: Pressure and Area Definitions and Fluid Force Application Locations



P_i, A_i - pressure and area i, respectively

LP_j = load point j (point of application of fluid force)

TABLE 4.1

DSP4 FLUID FORCES ON PIPE

Load Point	Fluid Force on Pipe at Load Point*
1	$\overline{F}_1 = (P_2A_2 - P_1A_1\sin 29°)\hat{i} + P_1A_1 \cos 29°\hat{j}$
2	$\overline{F}_2 = (P_3A_3 - P_2A_2)\hat{i}$
3	$\overline{F}_3 = P_5A_5\hat{i} + P_4A_4\hat{j}$
4	$\overline{F}_4 = P_7A_7 \cos 60° \hat{i} + P_7A_7 \sin 60° \hat{j} + P_6A_6\hat{k}$
5	$\overline{F}_5 = - P_7A_7 \cos 15° \hat{i} - P_7A_7 \sin 15° \hat{j}$

---

*Note: The unit vectors $\hat{i}$, $\hat{j}$, $\hat{k}$ correspond to the local coordinate systems at the load points (see Figure 4.6).

TABLE 4.2: RELATION OF PRESSURE P_i TO TRANSDUCER CHANNEL

Pressure	Corresponding Transducer	Flow Area (m^2)
P_1	RP2114	0.1083
P_2	RP2108	0.1083
P_3	RP2205	0.1083
P_4	RP2205	0.1083
P_5	RP2203	0.1018
P_6	RP2202	0.1018
P_7	RP2201	0.1018

FIGURE 4.6

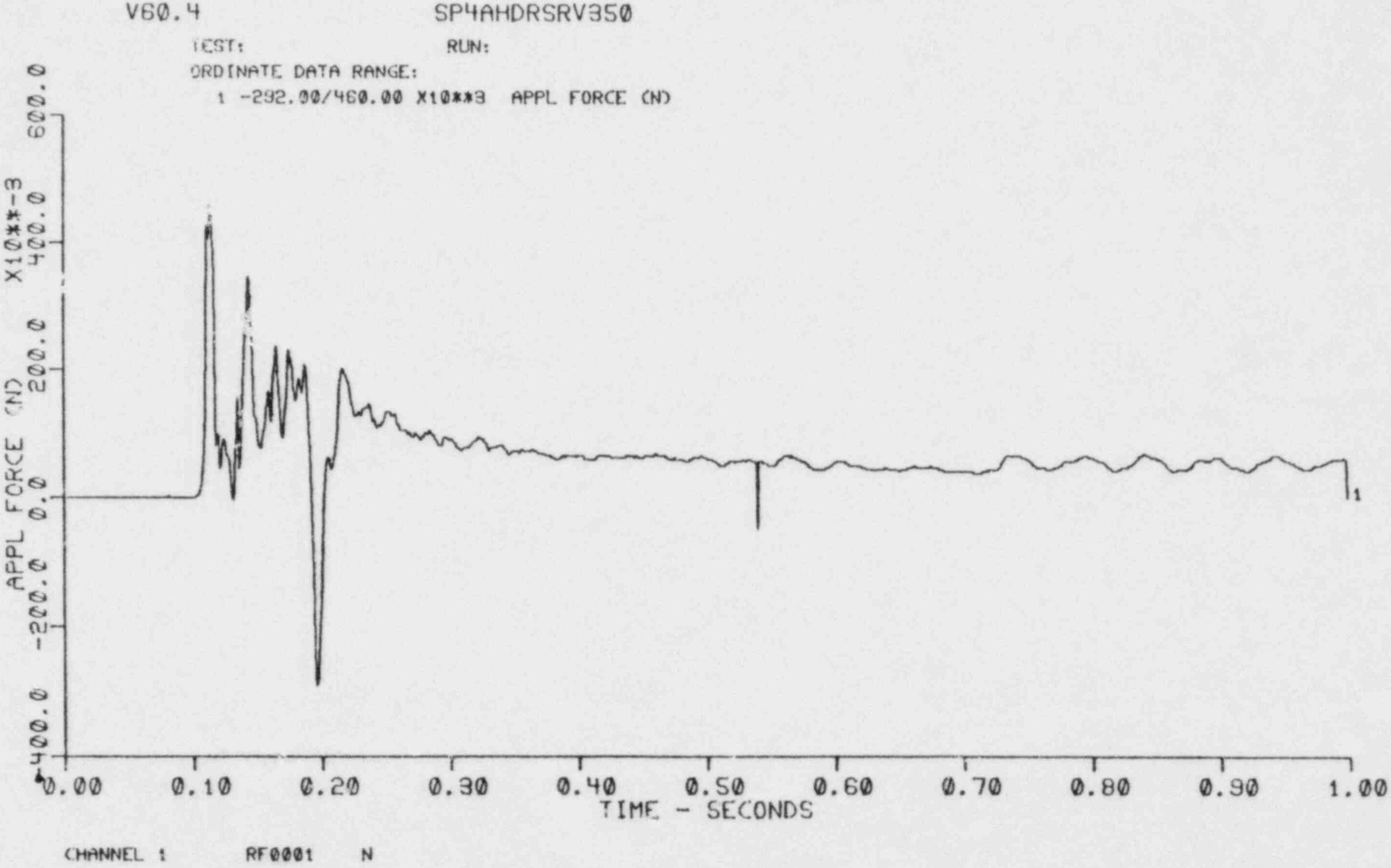

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
1 -292.00/460.00 X10**3 APPL FORCE (N)
APPL FORCE (N) X10**-3
600.0
400.0
200.0
0.0
-200.0
-400.0
1
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 1
RF0001
N

FIGURE 4.7

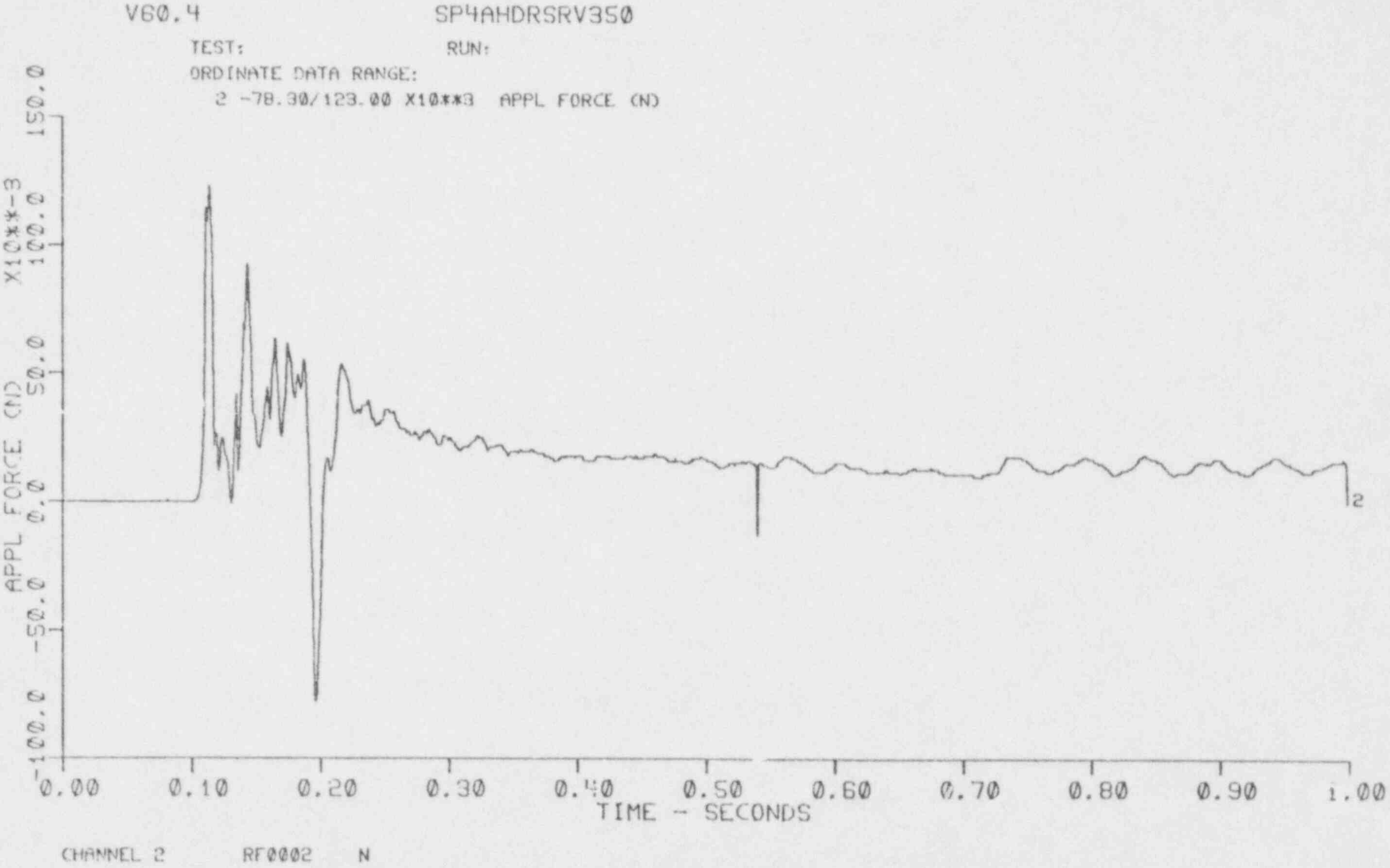

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
2 -78.30/123.00 X10**3 APPL FORCE (N)
APPL FORCE (N) X10**-3
150.0
100.0
50.0
0.0
-50.0
-100.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
2
CHANNEL 2
RF0002
N

FIGURE 4.8

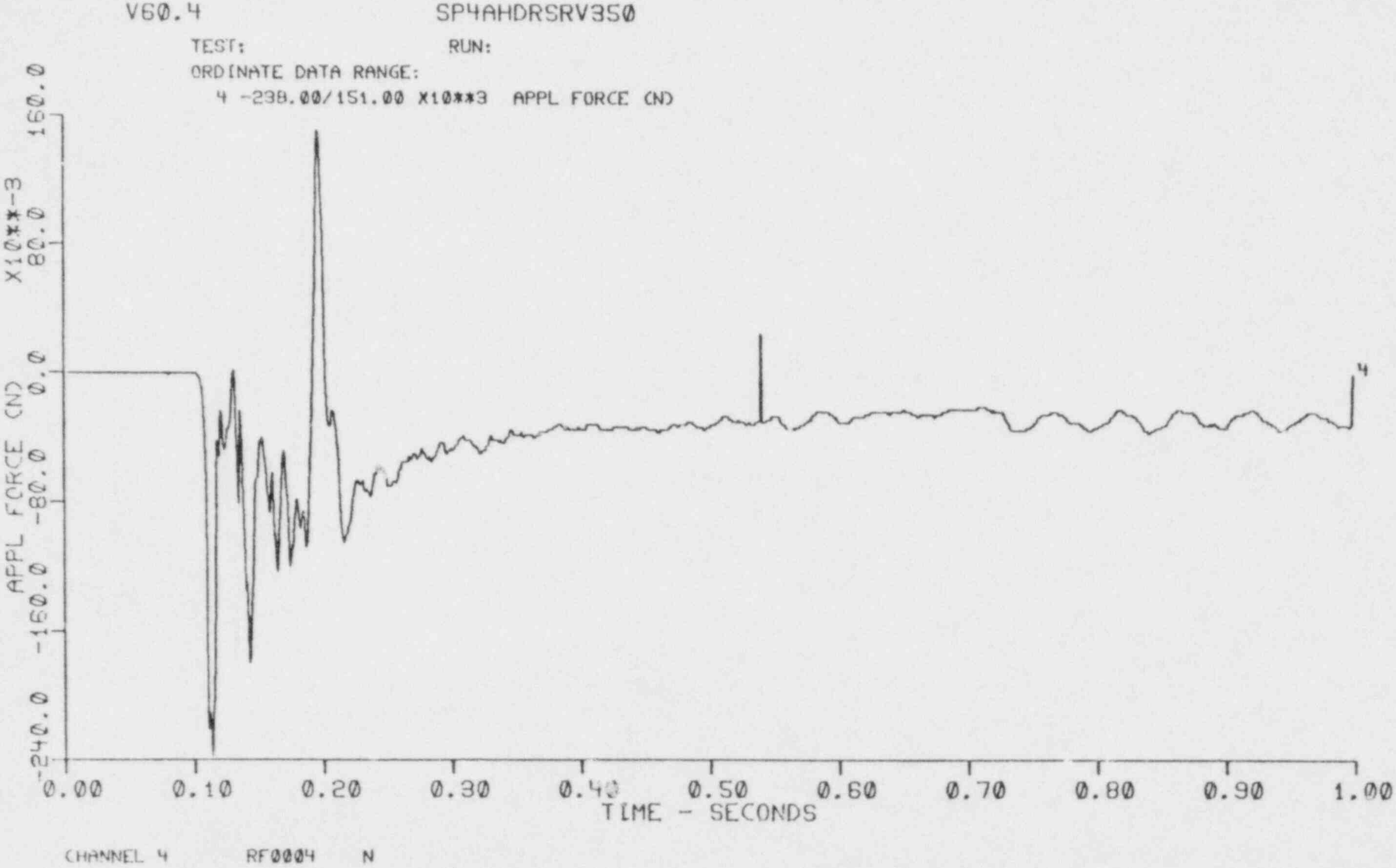
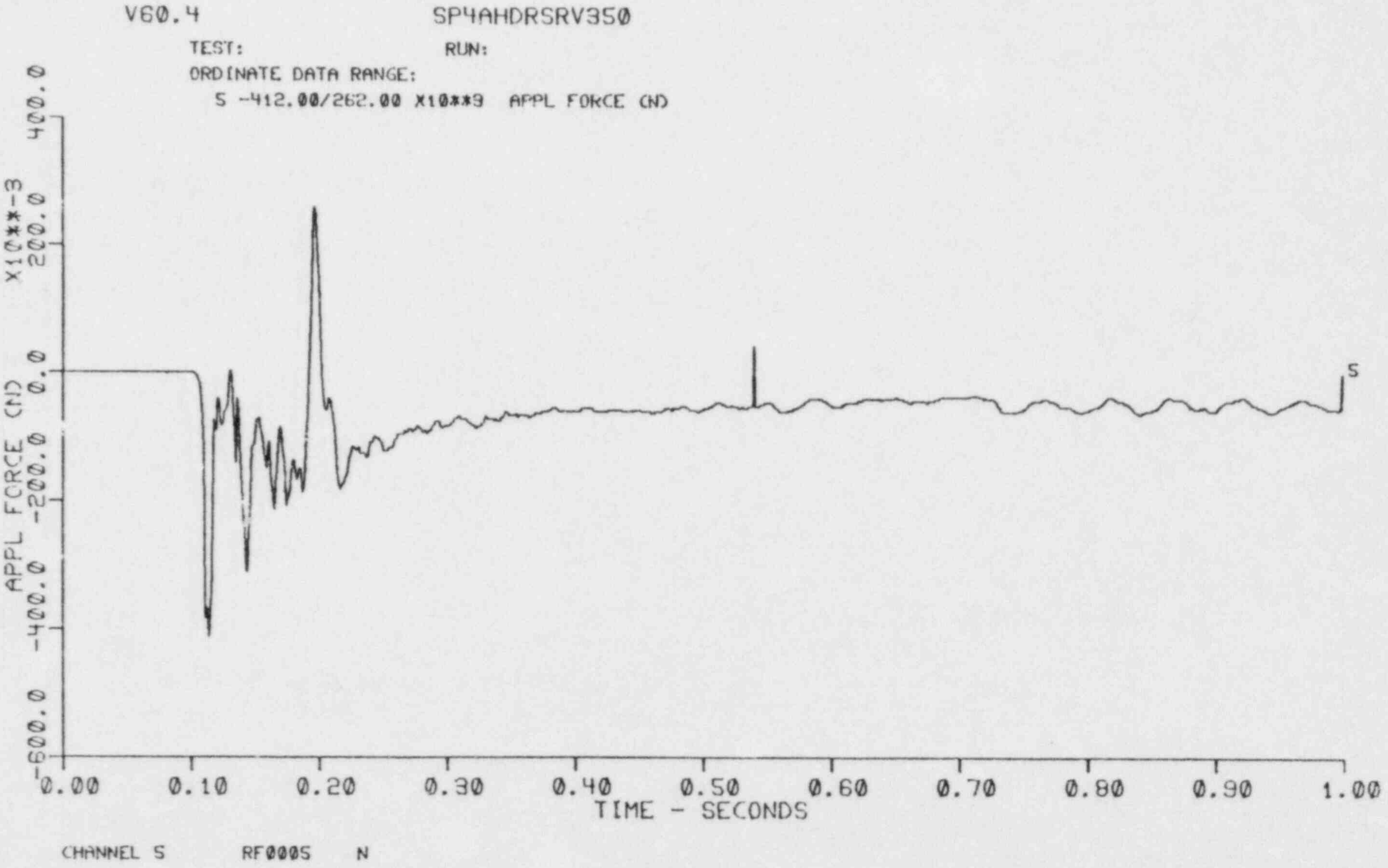

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
4 -238.00/151.00 X10**3 APPL FORCE (N)
X10**-3
APPL FORCE (N)
160.0
80.0
0.0
-80.0
-160.0
-240.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
4
CHANNEL 4
RF0004
N

FIGURE 4.9



V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
5 -412.00/262.00 X10**9 APPL FORCE (N)
X10**-3
400.0
200.0
0.0
-200.0
-400.0
-600.0
APPL FORCE (N)
5
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 5
RF0005
N

FIGURE 4.10

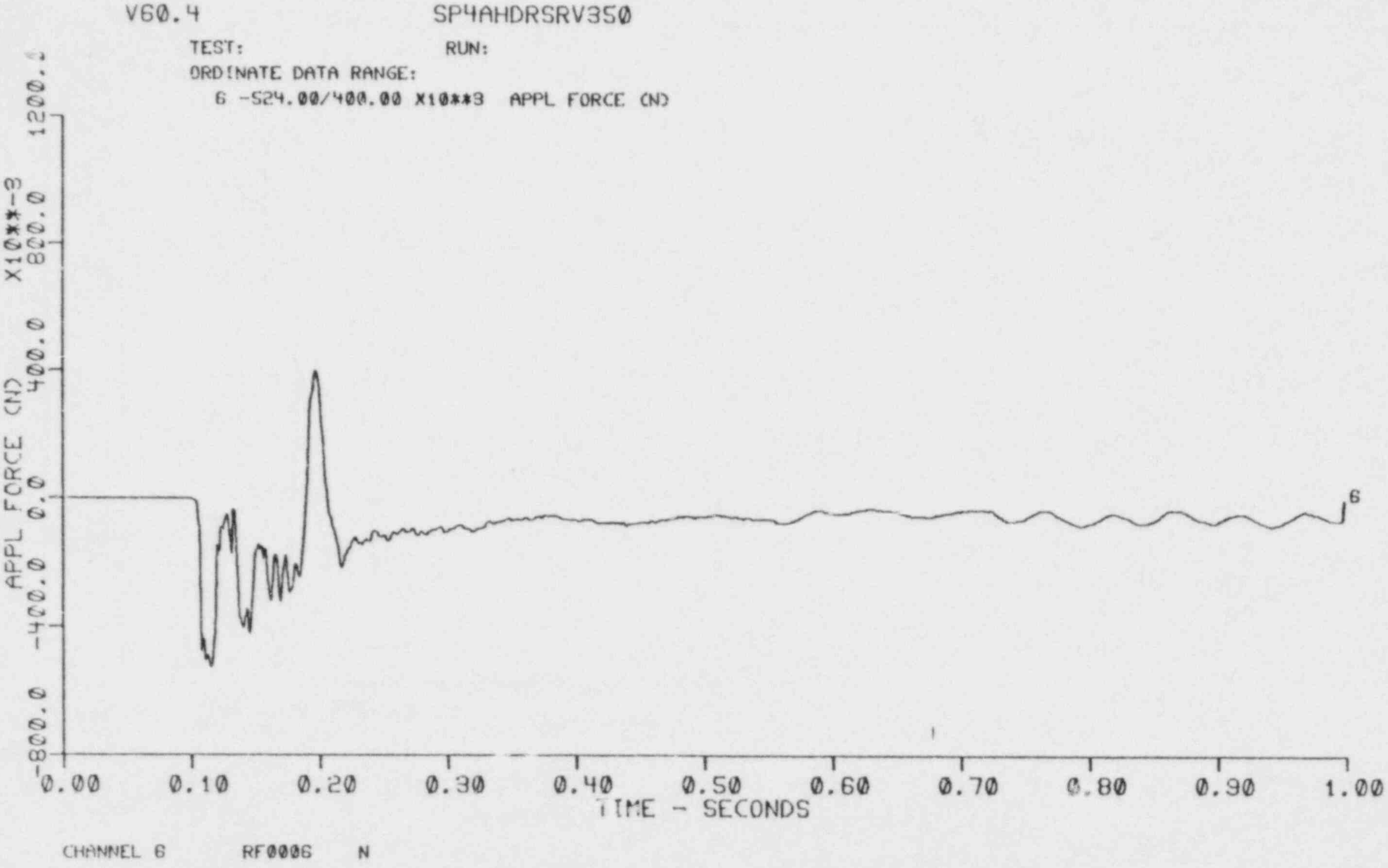

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
6 -524.00/400.00 X10**3 APPL FORCE (N)
X10**-3
APPL FORCE (N)
1200.0
800.0
400.0
0.0
-400.0
-800.0
6
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 6
RF0006
N

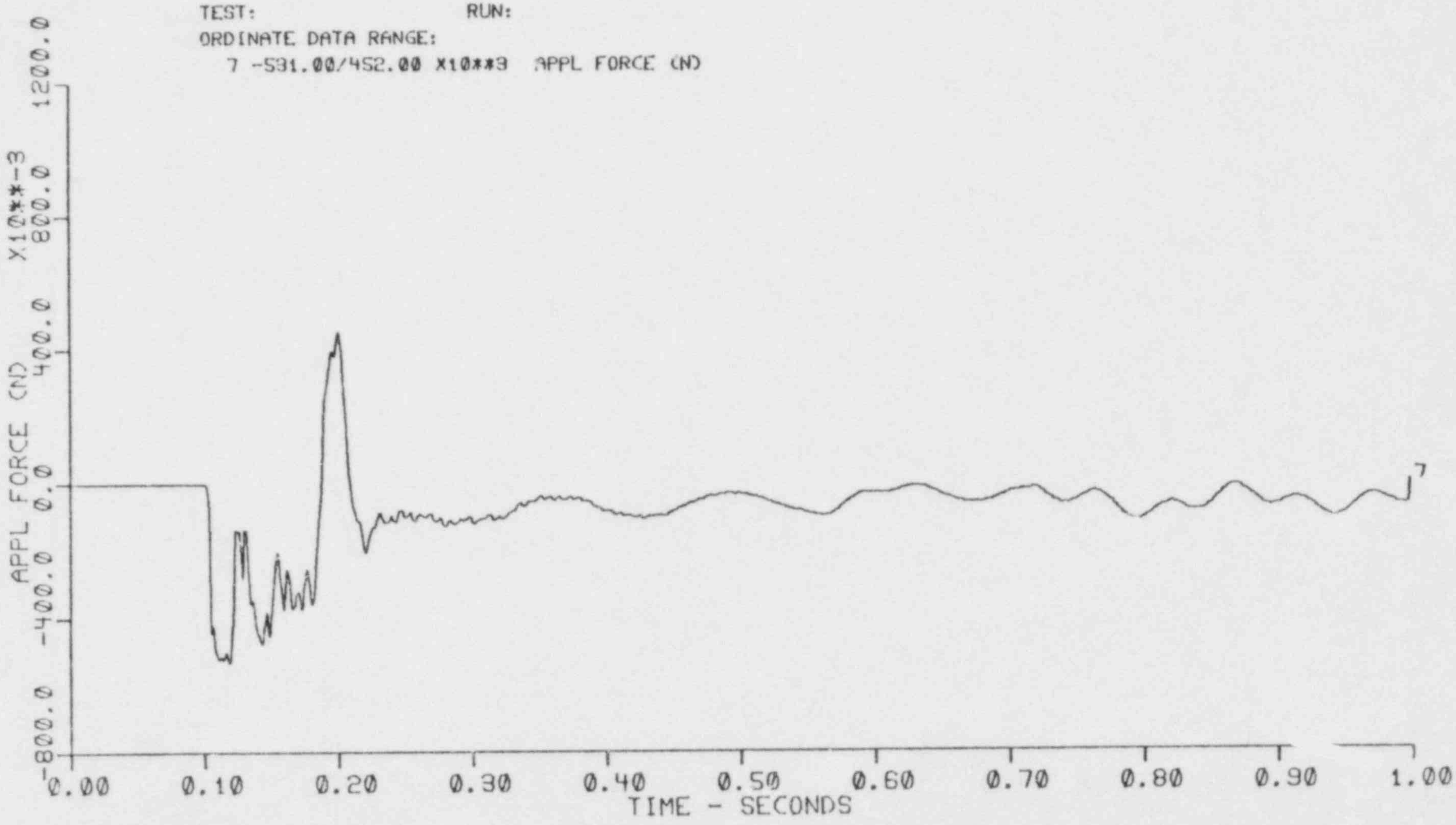
FIGURE 4.11

V60 4 SP4AHDRSRV350

TEST: RUN:

ORDINATE DATA RANGE:

7 -531.00/452.00 X10**3 APPL FORCE (N)



CHANNEL 7 RF0007 N

FIGURE 4.12

V60.4 SP4AHDRSRV350

TEST: RUN:

ORDINATE DATA RANGE:

8 -567.00/475.00 X10**9 APPL FORCE (N)

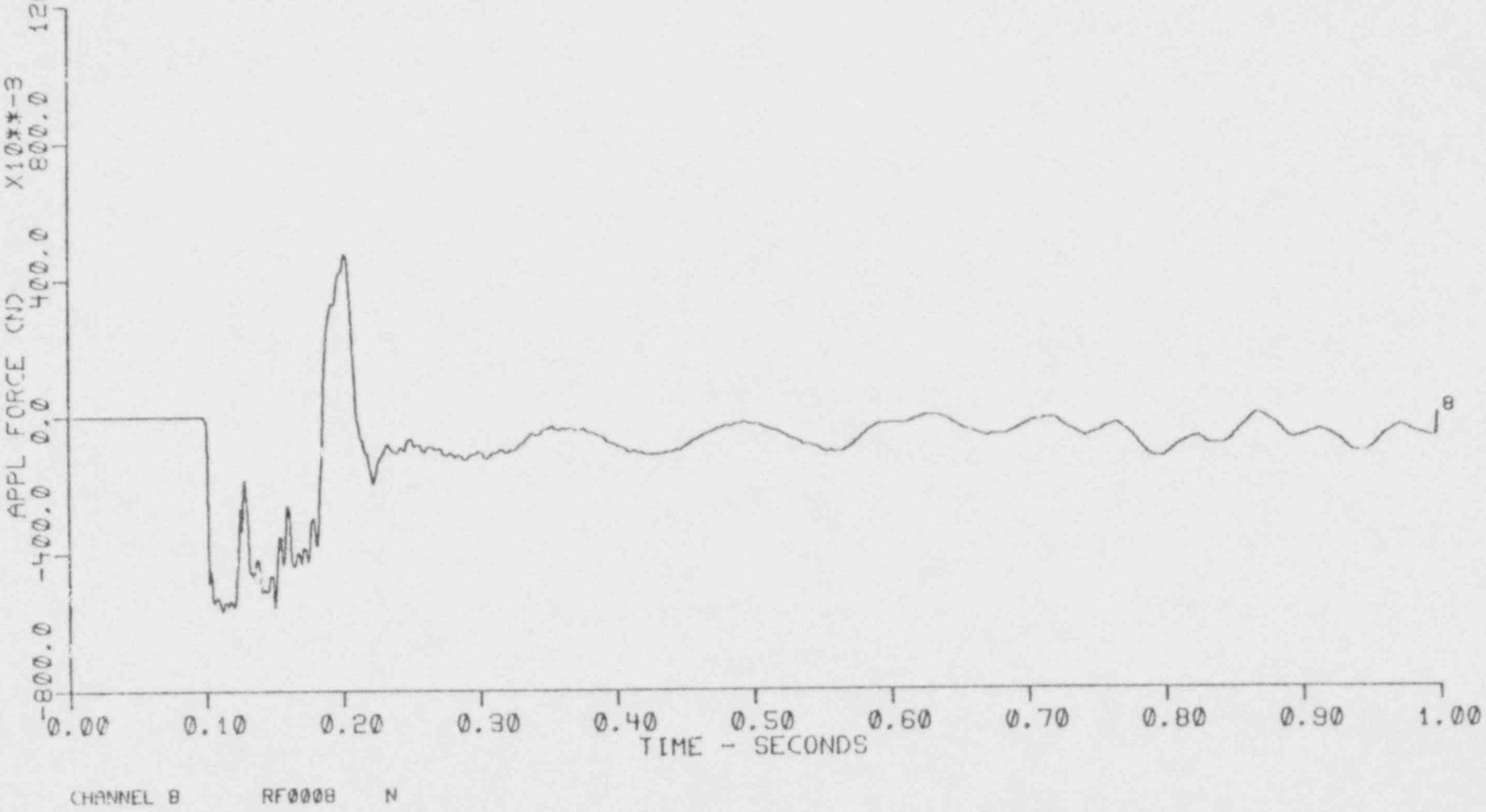


FIGURE 4.13

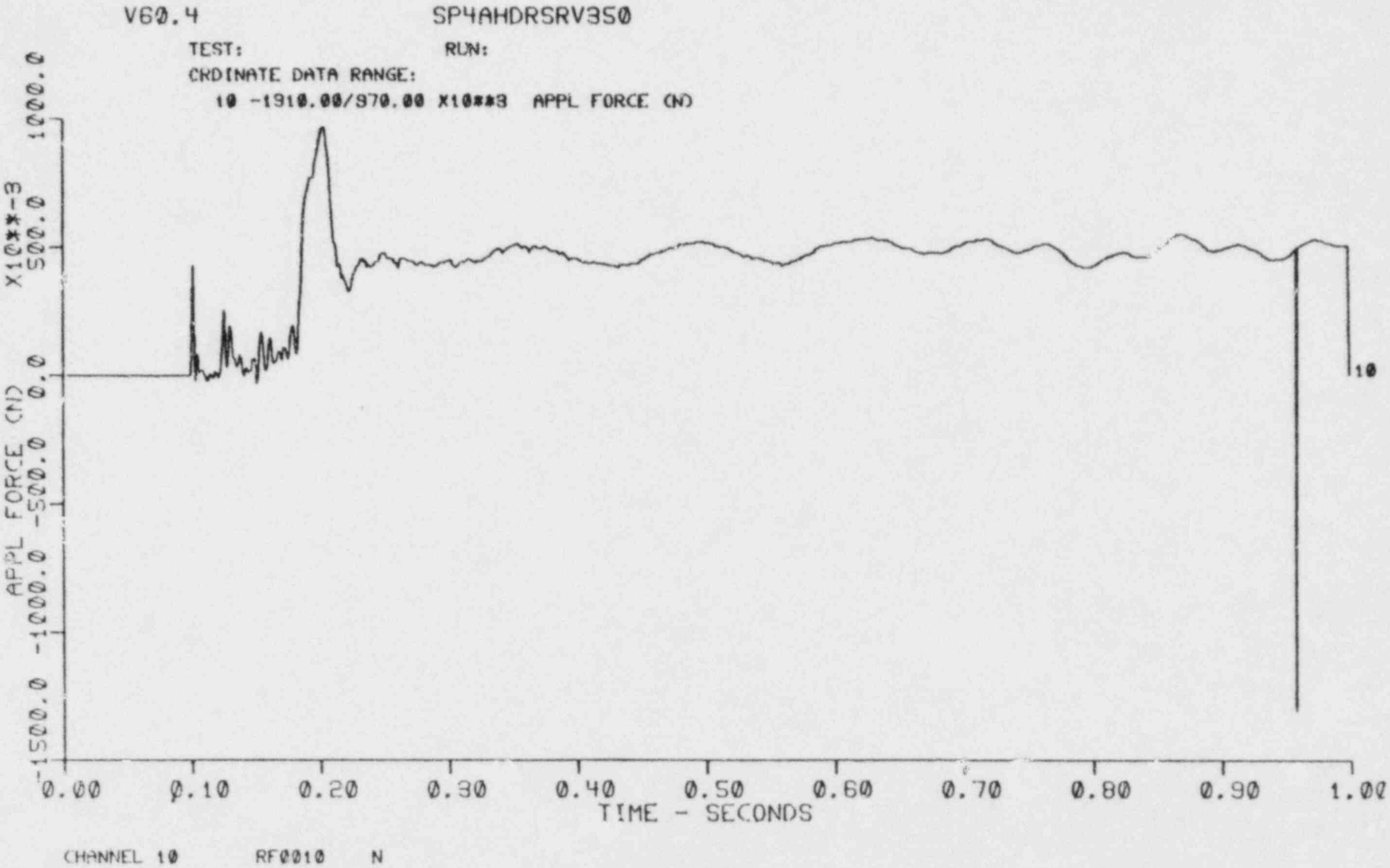

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
10 -1910.00/970.00 X10**3 APPL FORCE (N)
X10**-3
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
APPL FORCE (N)
10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 10
RF0010
N

FIGURE 4.14

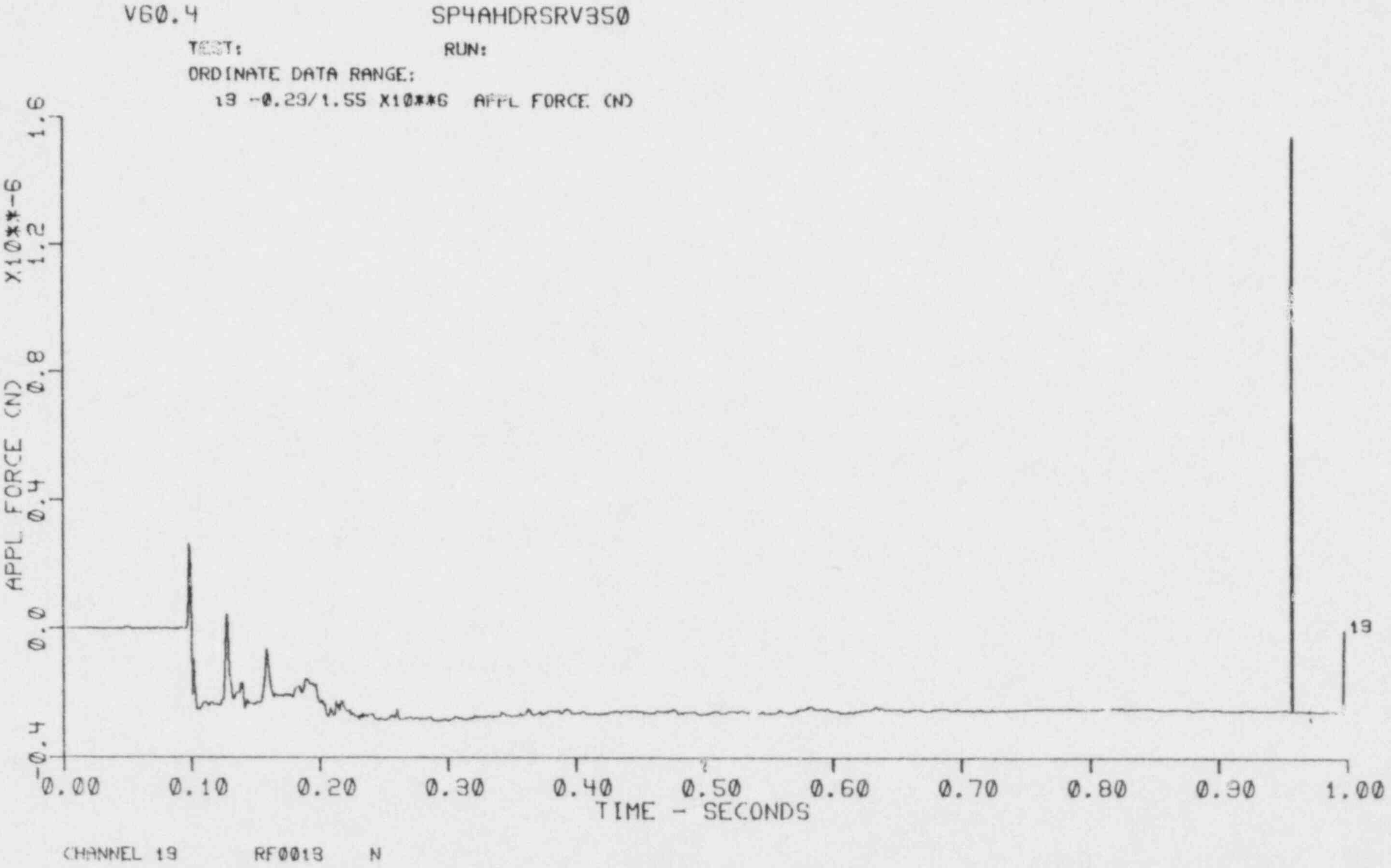

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
13 -0.23/1.55 X10**6 APPL FORCE (N)
APPL FORCE (N) X10**-6
1.6
1.2
0.8
0.4
0.0
-0.4
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
13
CHANNEL 13
RF0013
N

FIGURE 4.15

(Problem with file information for RF0014)

TABLE 4.3

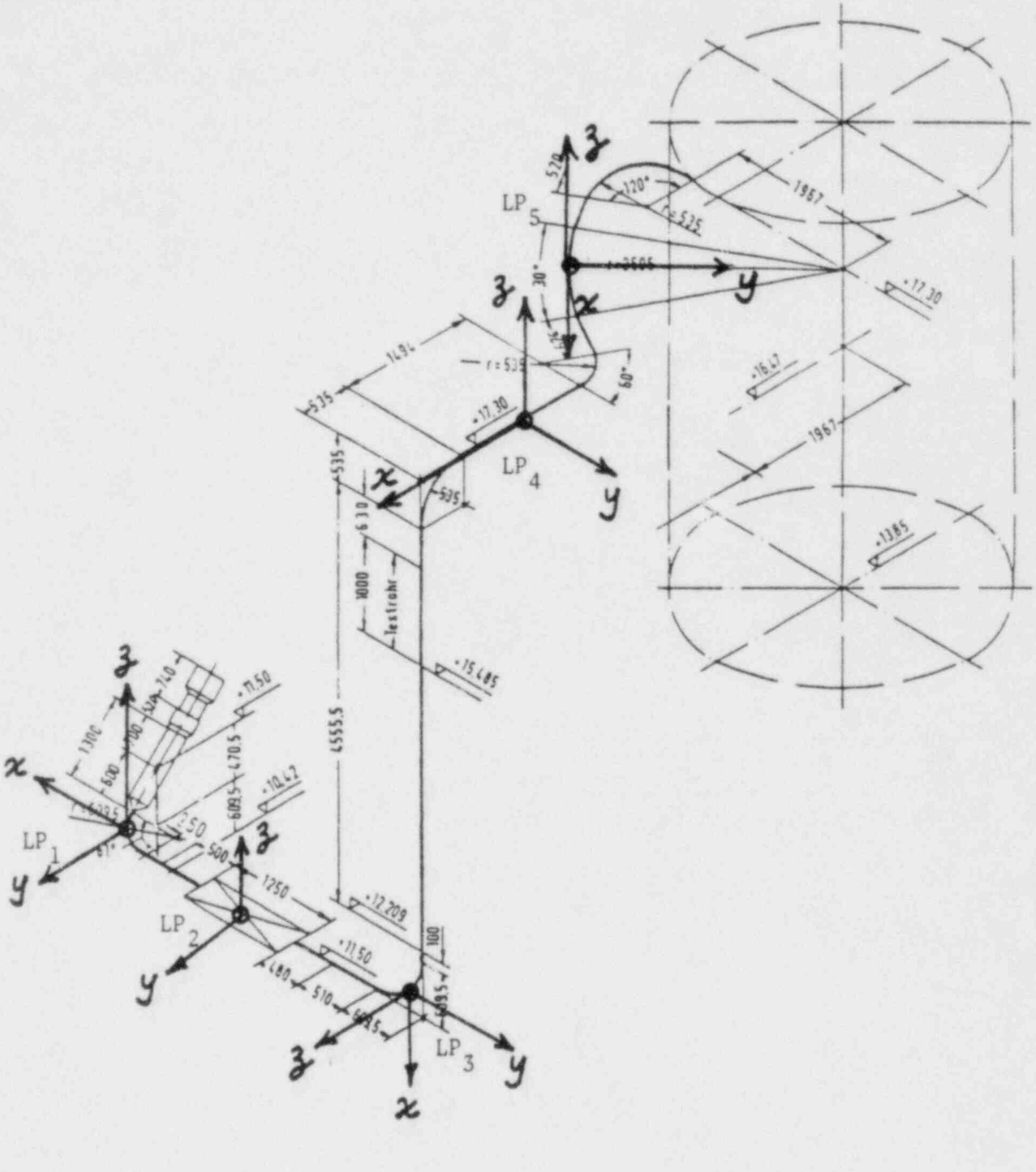
LOCATION AND DIRECTION OF APPLIED FLUID FORCES

Force Number*	Load Point (LP)	Location of Force (ANCO Node)	Direction of Force (Local Coordinates)**
RF0001	5	11	x
RF0002	5	11	y
RF0003	5	11	z
RF0004	4	18	x
RF0005	4	18	y
RF0006	4	18	z
RF0007	3	37	x
RF0008	3	37	y
RF0009	3	37	z
RF0010	2	43	x
RF0011	2	43	y
RF0012	2	43	z
RF0013	1	49	x
RF0014	1	49	y
RF0015	1	49	z

---

*This corresponds to the force headers of file #2.

**See Figure 4.16 for the definition of these directions.



LP_j = load point j

FIGURE 4.16: Local Coordinate Directions for Applied Fluid Forces.

TABLE 4.4

EXTREME VALUES OF FLUID FORCES

Force Number	ANCO Node	Force Direction	Minimum/Maximum Value/10^3 (N)
RF0001	11	x	-292/460
RF0002	11	y	-78/123
RF0004	18	x	-238/151
RF0005	18	y	-412/262
RF0006	18	z	-524/400
RF0007	37	x	-531/452
RF0008	37	y	-567/475
RF0010	43	x	-131/970
RF0013	49	x	-290/1550

5.0 STRUCTURAL DYNAMIC SIMULATION OF URL BLOWDOWN EVENT (DSP4a)

The finite element model discussed in Section 3.0 and the fluid forces presented in Section 4.0 were the basis for the response calculations required for German Standard Problem 4a (DSP4a). In performing the response calculations, several items were of concern; they were: (1) damping to be used; (2) the integration interval; and (3) nonlinear versus linear simulation methods.

No data was available on the damping of the portion of the URL pipe system involved in the DSP4a simulation. Damping data was available for the remainder of the pipe system. It typically varied from 3.0 to 6.0 percent of critical. It would be expected that the damping for the portion of the URL system not involved in DSP4a would be higher than that for the pipe leg of interest. This is because the leg of interest did not have any supports (sway braces, spring hangers, etc.) connected to it, whereas, the remainder of the system did. (The pipe supports generally increased the losses in the system.) For this reason it was decided to use damping values intermediate to the extreme values of 3.0% and 6.0%. The damping was chosen to be between 3.0% and 4.5% of critical. It should be noted that the transient response solution for DSP4a is not extremely sensitive to damping changes over a small damping domain (i.e., 3.0% to 4.0%). For this reason, choosing intermediate damping values seems to be reasonable.

The structural equations of motion were integrated using a direct integration scheme (Newmark method). The integration interval was chosen to be equal to the discretization interval used for digitizing the DSP4 data (Δt = 0.0002 second). With this time interval and using 16 time points per cycle, it is possible to define a transient signal of up to 312.5 Hz. The fluid pressure, for DSP4 type events, generally has its major frequency content in the 50 Hz to 100 Hz range. Hence, the chosen integration interval should be more than adequate (Nyquist sampling theorum says that a Δt of 0.0002 seconds is sufficient to detect transients up to 2500 Hz while experience indicates that such a Δt will certainly be sufficient for transients up to 1200 Hz).

The proportional damping coefficients α and β ($C = \alpha M + \beta K$, where C, M, and K are the damping, mass, and stiffness matrices, respectively) were chosen to be 1.20 and 6.35×10^{-5}, respectively. This gives an equivalent modal damping of 4.5% at 5 Hz and 100 Hz and a minimum damping of 3.0% between 5 Hz and 100 Hz.

In simulating the structural dynamic event, a linear analysis approach was selected. This decision was made because it was not known if the pipe would experience nonlinear deformation; hence, a standard approach dictated that a linear analysis be performed first, and, only if necessary, a nonlinear analysis would be performed (this would not be done for this present task).

The linear analysis was performed and the plotted results shown in Figures 5.1 to 5.42. Table 5.1 gives the minimum and maximum values for the structural response quantities specified by DSP4a. Appendix C lists the computer code that was written to process the EASE2 output. It was used to compute additional stress information and perform the necessary coordinate transformations of the displacement and acceleration results.

FIGURE 5.1

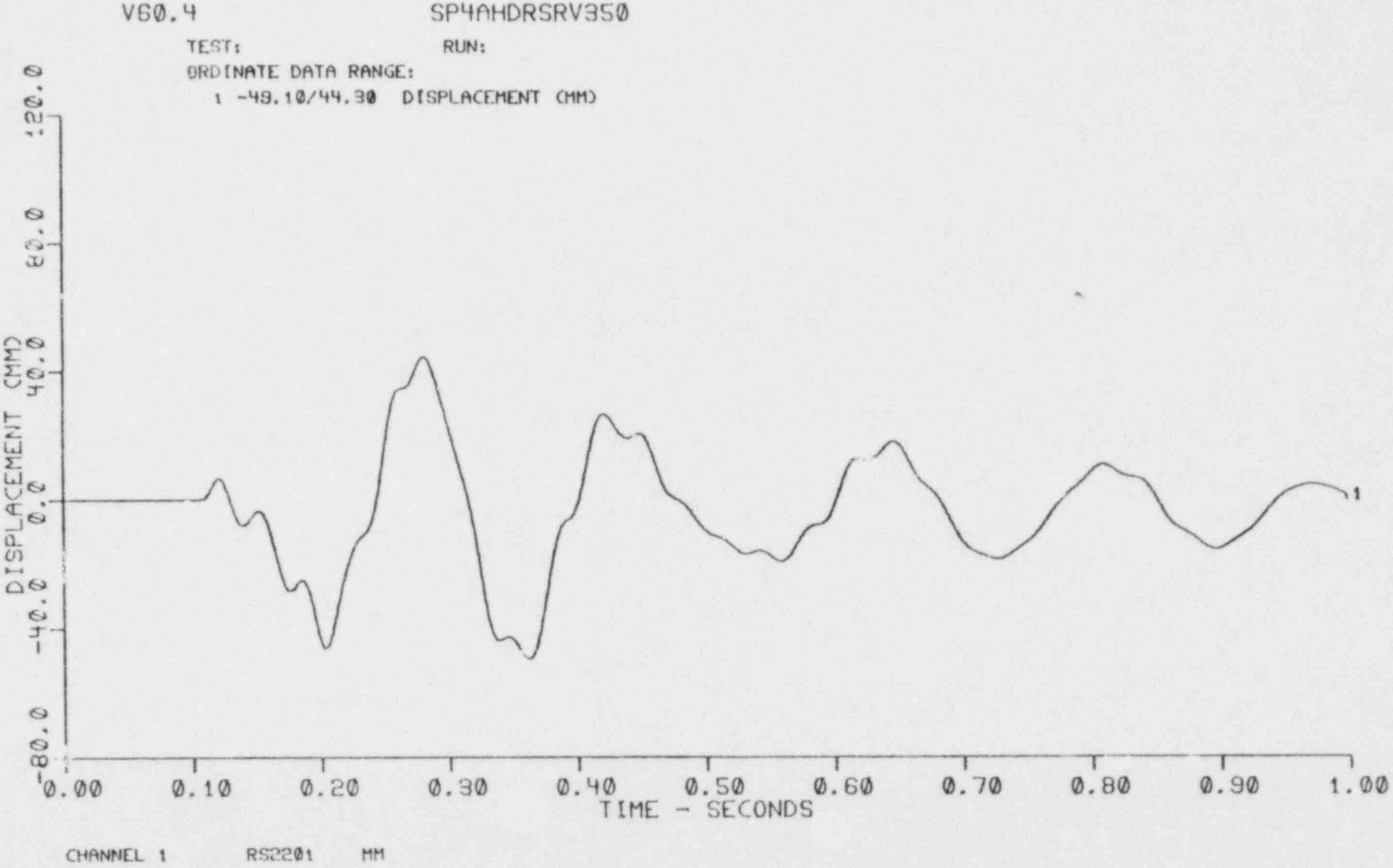

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
1 -49.10/44.30 DISPLACEMENT (MM)
DISPLACEMENT (MM)
120.0
80.0
40.0
0.0
-40.0
-80.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
1
CHANNEL 1
RS2201
MM

FIGURE 5.2

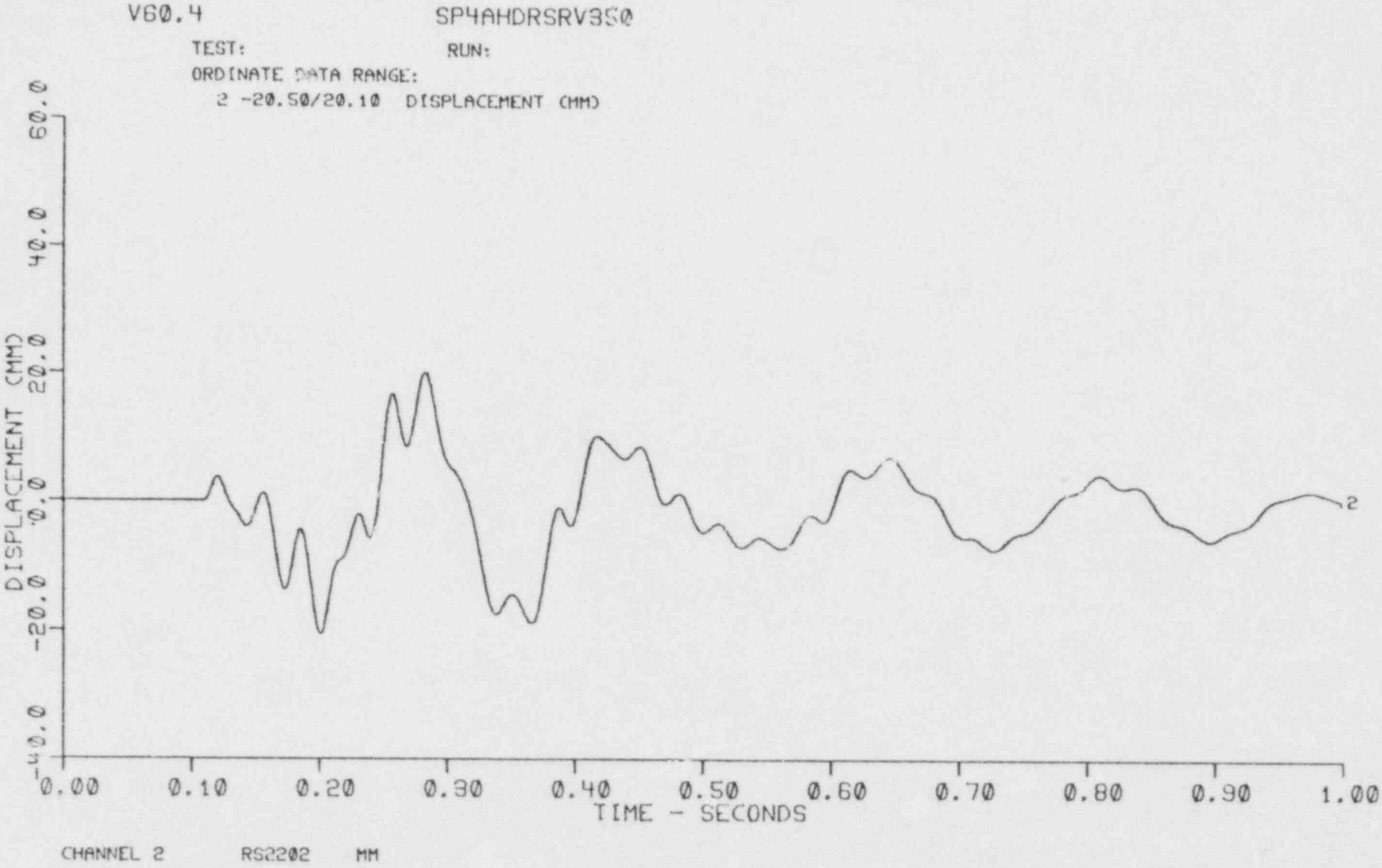

V60.4
SP4AHDRSRV3S0
TEST:
RUN:
ORDINATE DATA RANGE:
2 -20.50/20.10 DISPLACEMENT (MM)
60.0
40.0
20.0
0.0
-20.0
-40.0
DISPLACEMENT (MM)
2
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 2
RS2202
MM

FIGURE 5.3

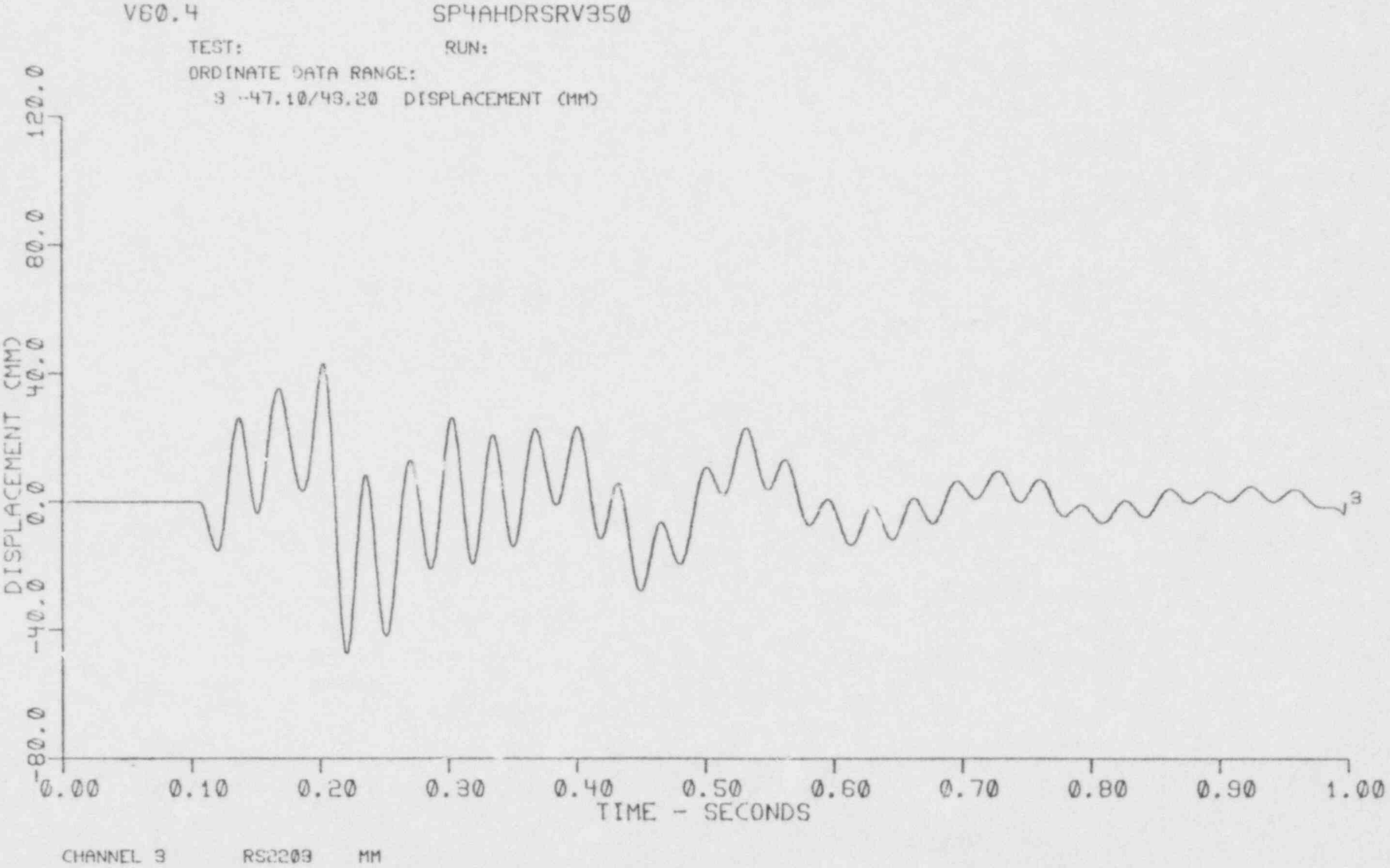

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
3 -47.10/43.20 DISPLACEMENT (MM)
DISPLACEMENT (MM)
120.0
80.0
40.0
0.0
-40.0
-80.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
3
CHANNEL 3
RS2203
MM

FIGURE 5.4

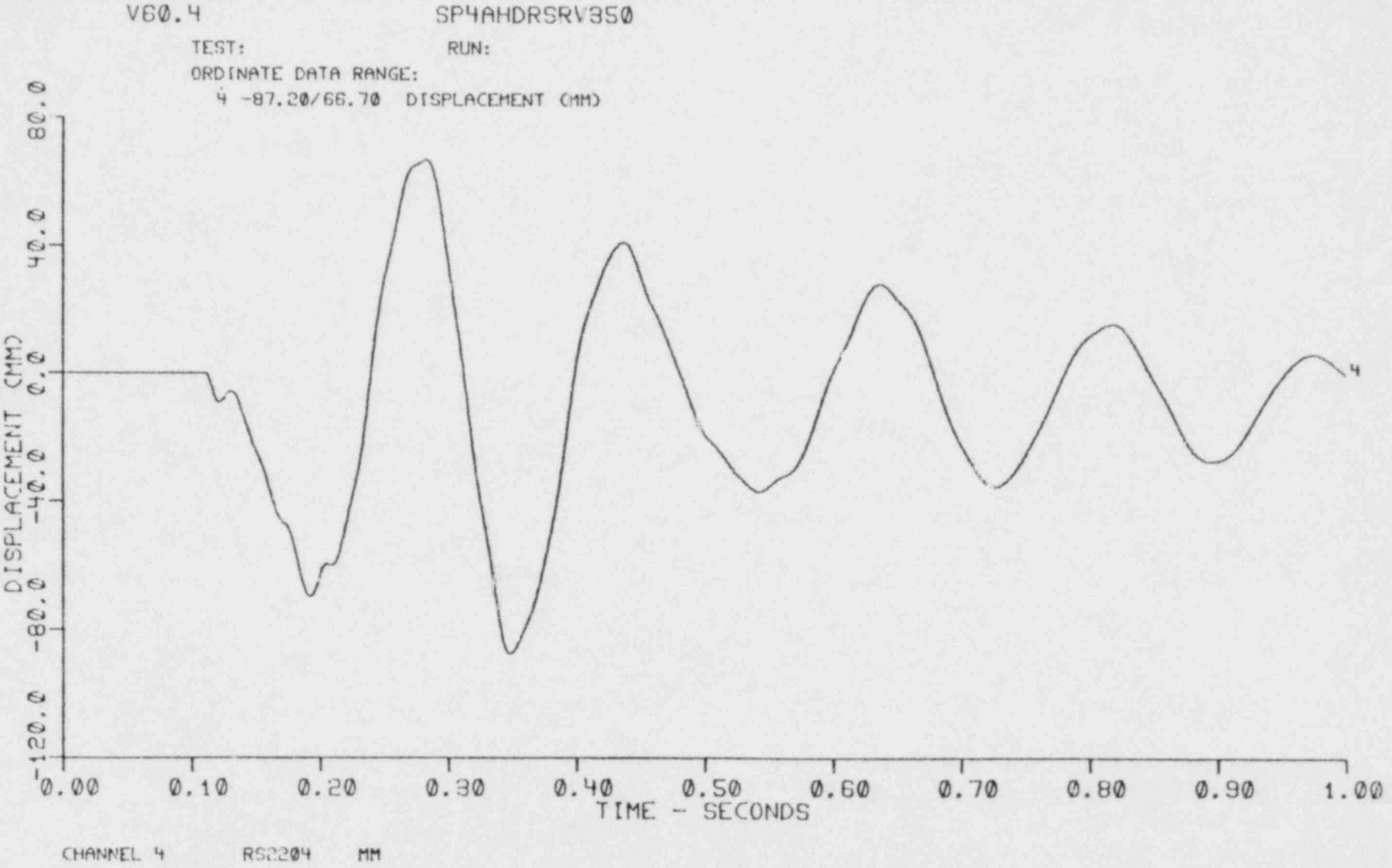

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
4 -87.20/66.70 DISPLACEMENT (MM)
DISPLACEMENT (MM)
80.0
40.0
0.0
-40.0
-80.0
-120.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
4
CHANNEL 4
RS2204
MM

FIGURE 5.5

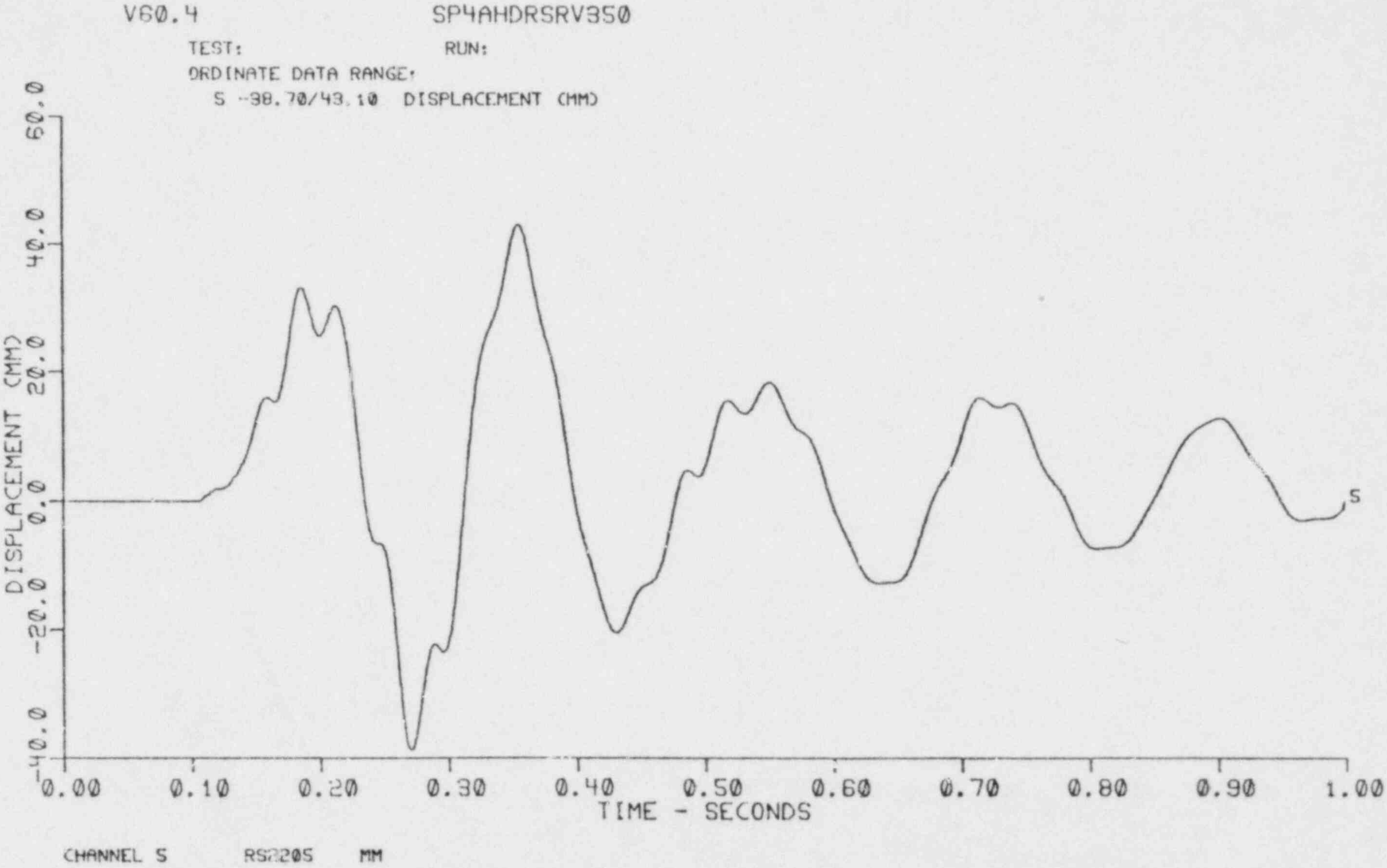

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
S -38.70/43.10 DISPLACEMENT (MM)
DISPLACEMENT (MM)
60.0
40.0
20.0
0.0
-20.0
-40.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
S
CHANNEL S
RS220S
MM

FIGURE 5.6

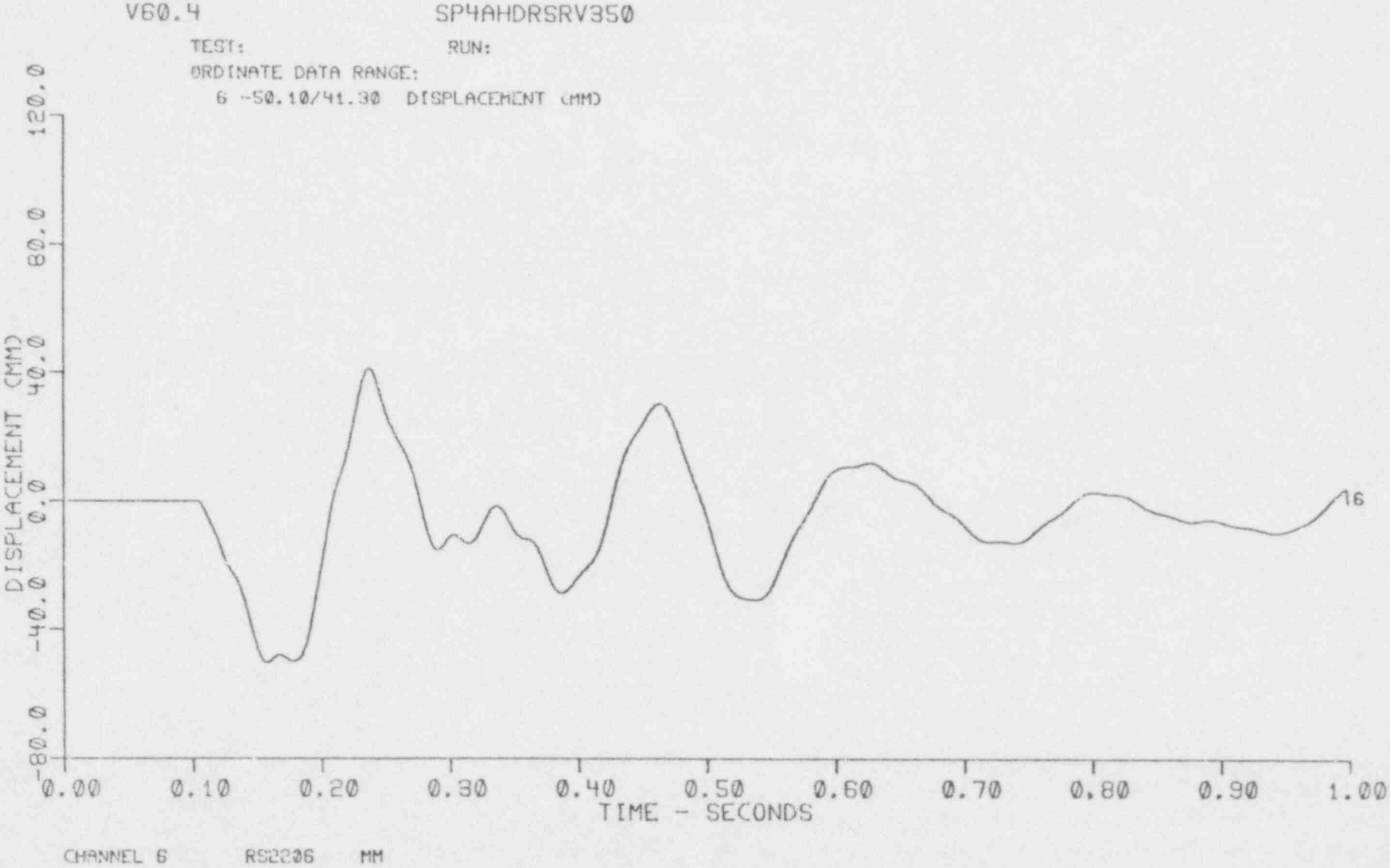

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
6 -50.10/41.30 DISPLACEMENT (MM)
DISPLACEMENT (MM)
120.0
80.0
40.0
0.0
-40.0
-80.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
6
CHANNEL 6
RS2206
MM

FIGURE 5.7

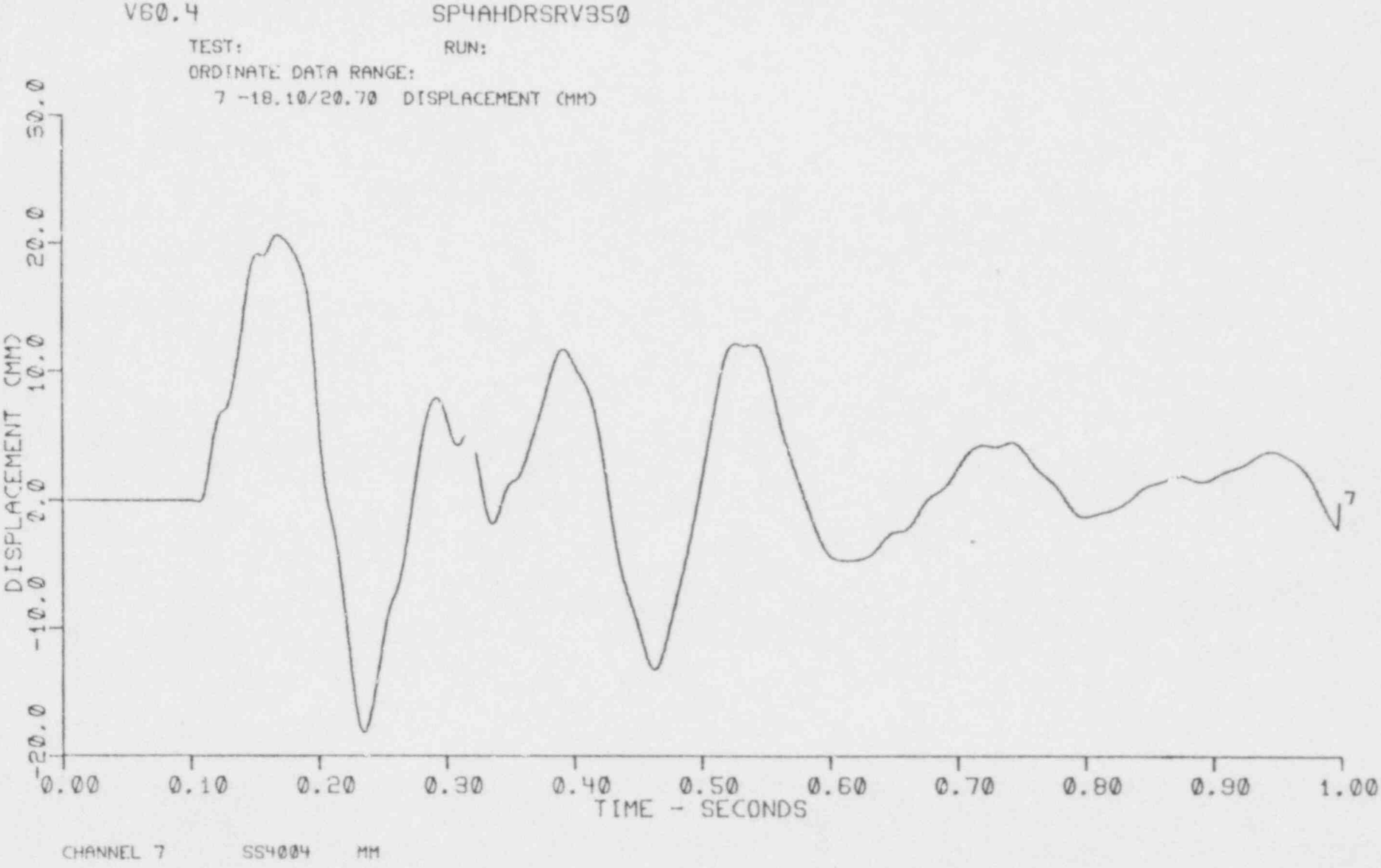

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
7 -18.10/20.70 DISPLACEMENT (MM)
30.0
20.0
10.0
0.0
-10.0
-20.0
DISPLACEMENT (MM)
7
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 7
SS4004
MM

FIGURE 5.8

V60.4 SP4AHDRSRV350

TEST: RUN:

ORDINATE DATA RANGE:

8 -1.17/1.59 DISPLACEMENT (MM)

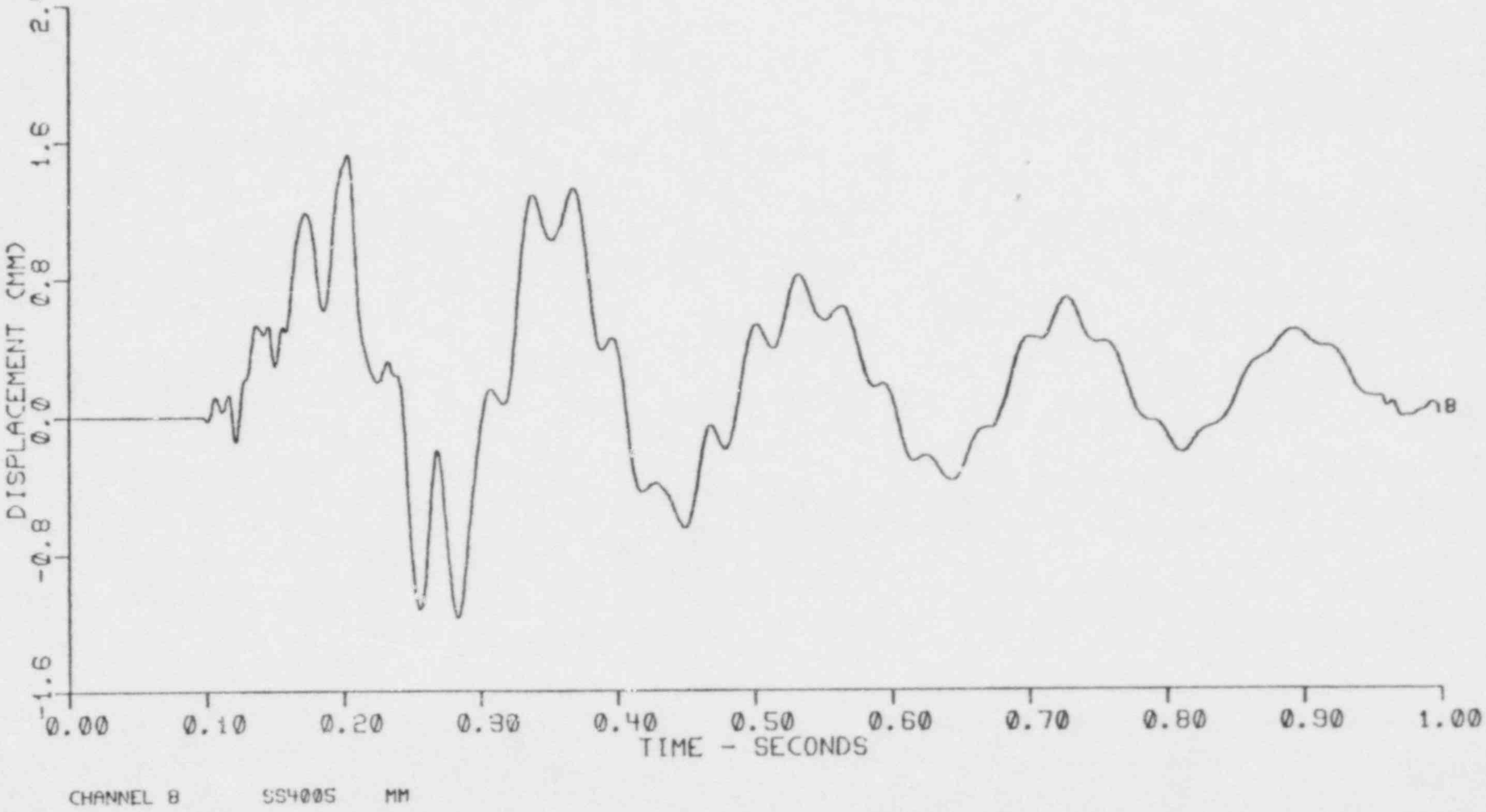


FIGURE 5.9

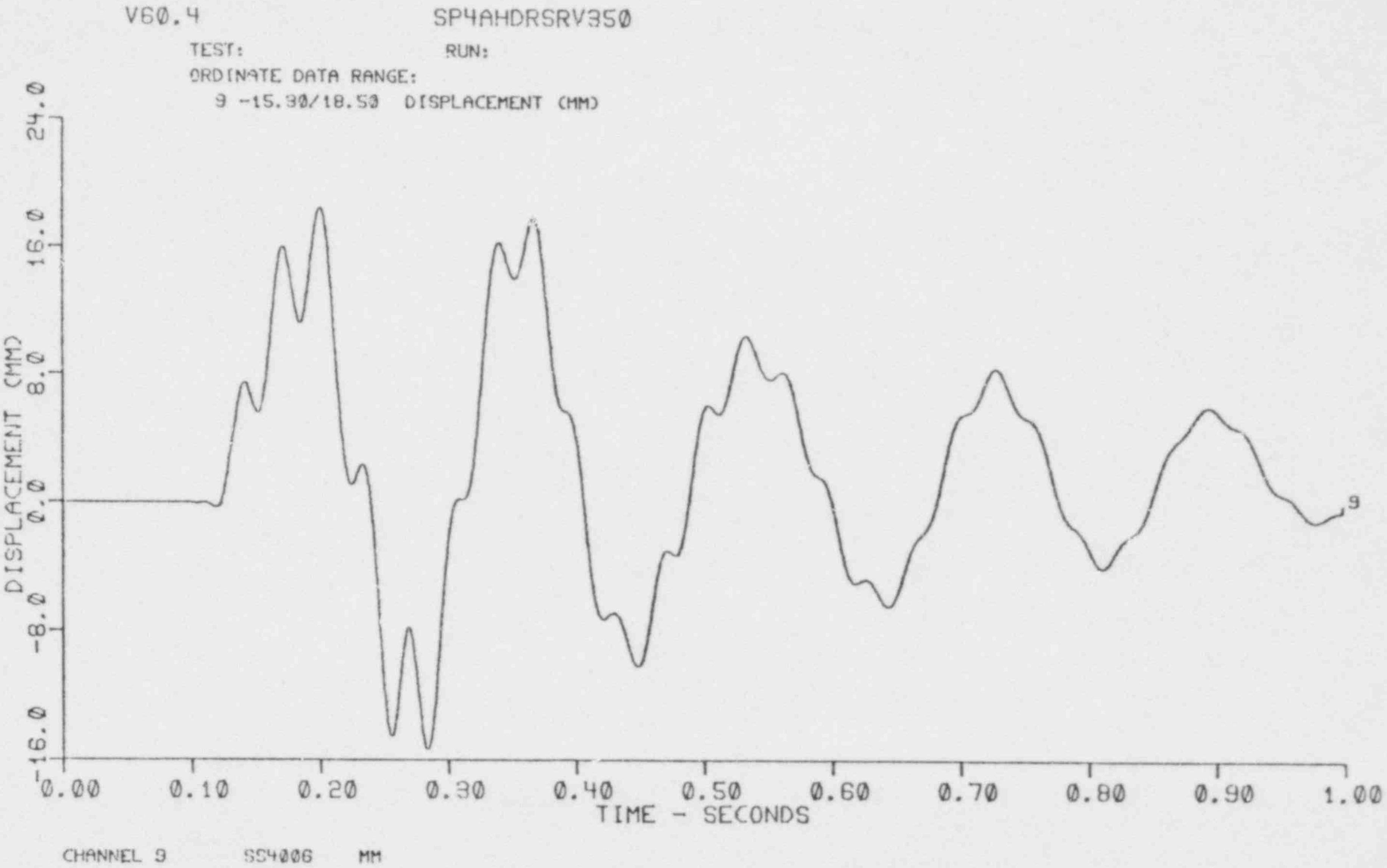

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
9 -15.30/18.50 DISPLACEMENT (MM)
DISPLACEMENT (MM)
24.0
16.0
8.0
0.0
-8.0
-16.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
9
CHANNEL 9
SS4006
MM

FIGURE 5.10

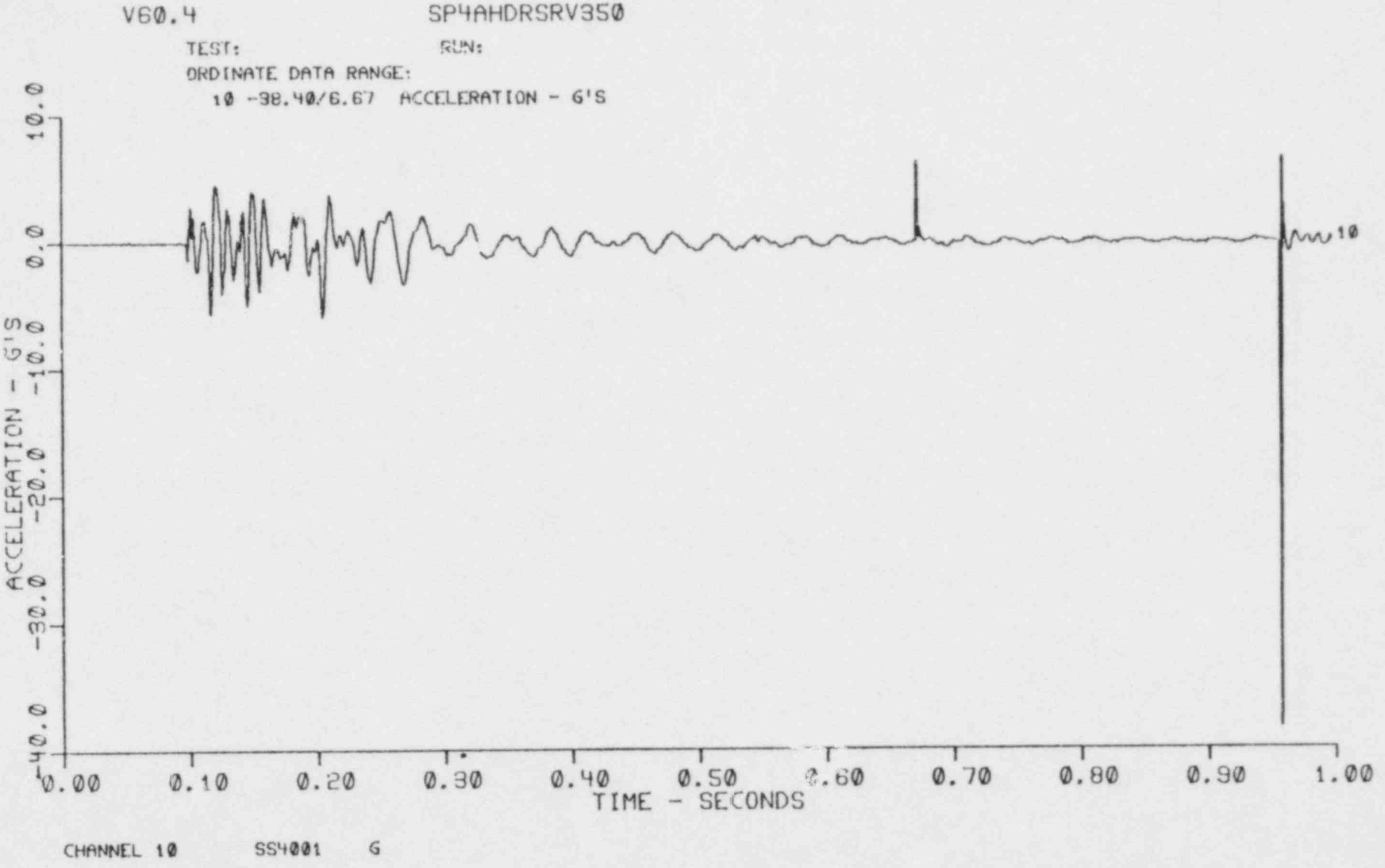

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
10 -38.40/6.67 ACCELERATION - G'S
10.0
0.0
-10.0
-20.0
-30.0
-40.0
ACCELERATION - G'S
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
10
CHANNEL 10
SS4001
G

FIGURE 5.11

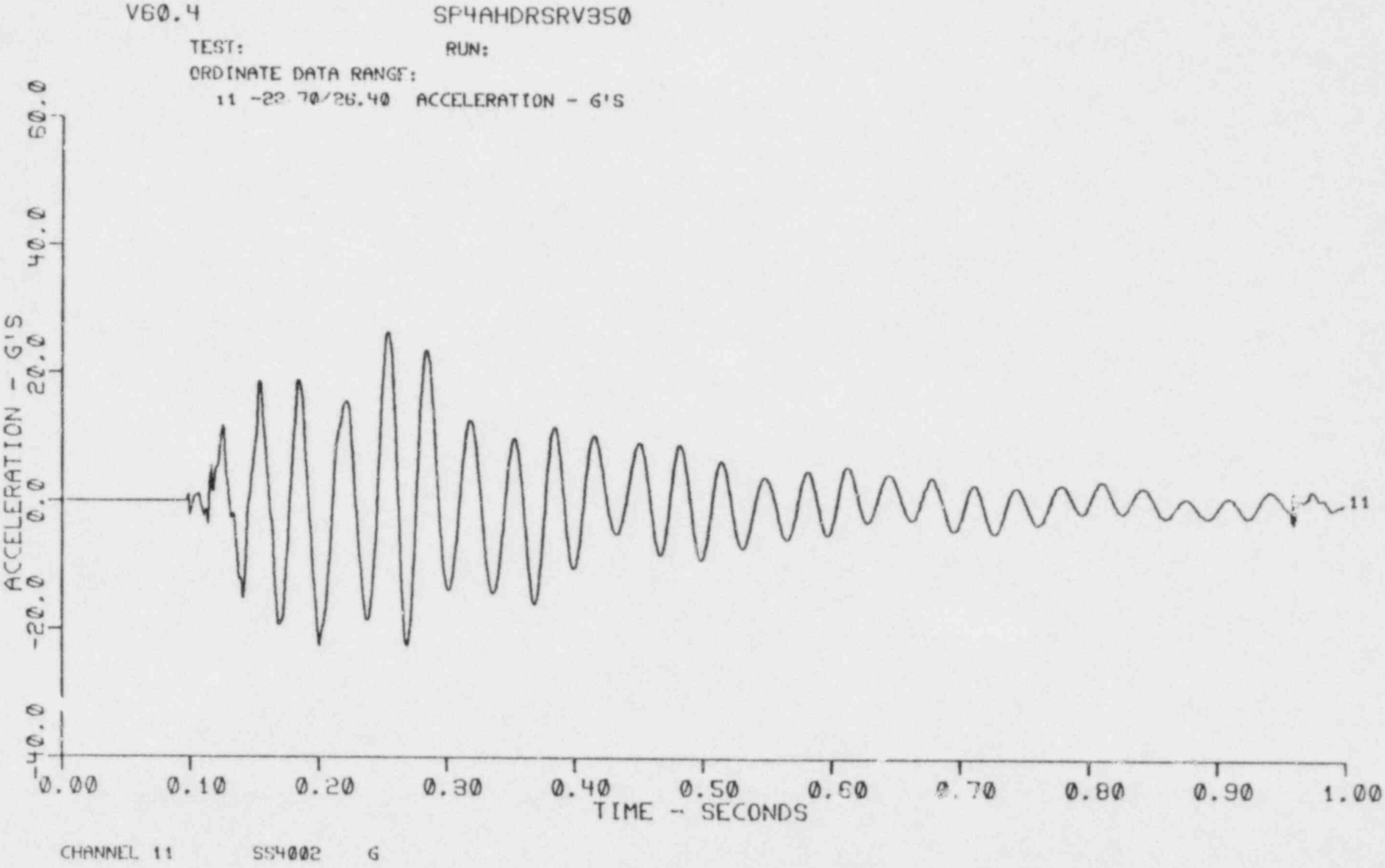

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
11 -22.70/26.40 ACCELERATION - G'S
ACCELERATION - G'S
60.0
40.0
20.0
0.0
-20.0
-40.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
11
CHANNEL 11
SS4002
G

FIGURE 5.12

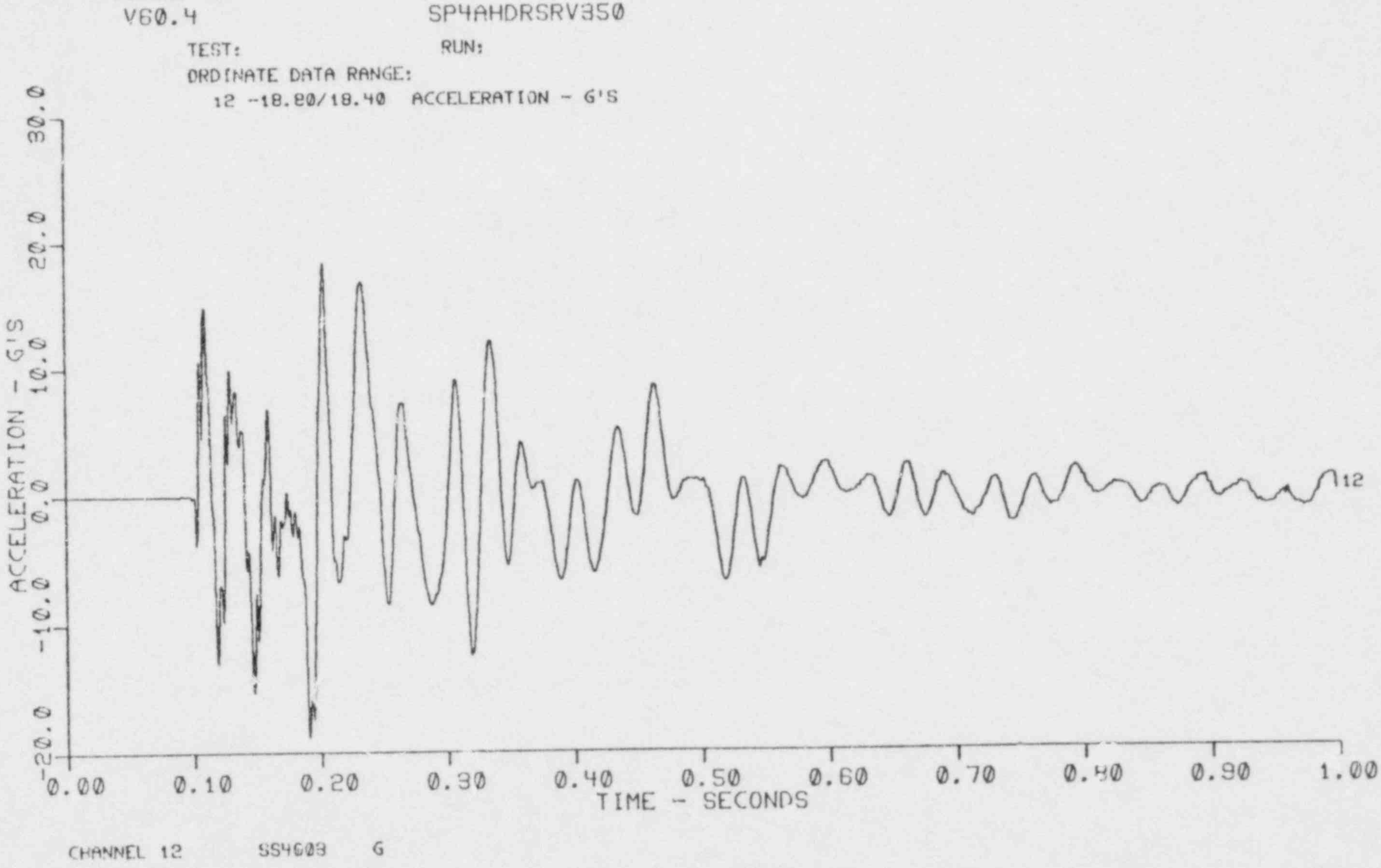

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
12 -18.80/18.40 ACCELERATION - G'S
ACCELERATION - G'S
30.0
20.0
10.0
0.0
-10.0
-20.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
12
CHANNEL 12
SS4608
G

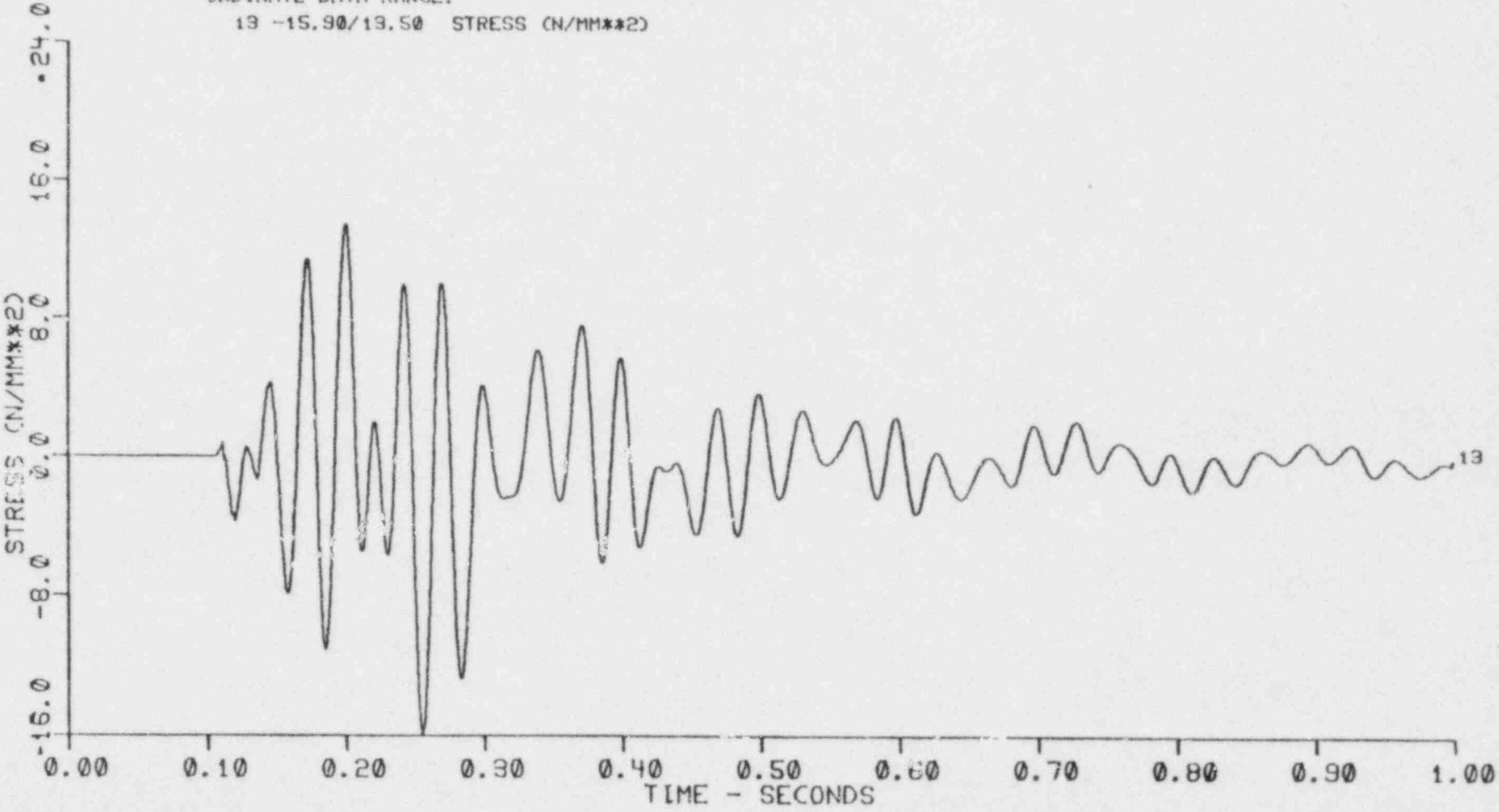
FIGURE 5.13

V60.4 SP4AHDRSRV350

TEST: RUN:

ORDINATE DATA RANGE:

13 -15.90/13.50 STRESS (N/MM**2)



CHANNEL 13 PK1010 N/MM2

FIGURE 5.14

(Problem with File Information for RK 2010)

FIGURE 5.15

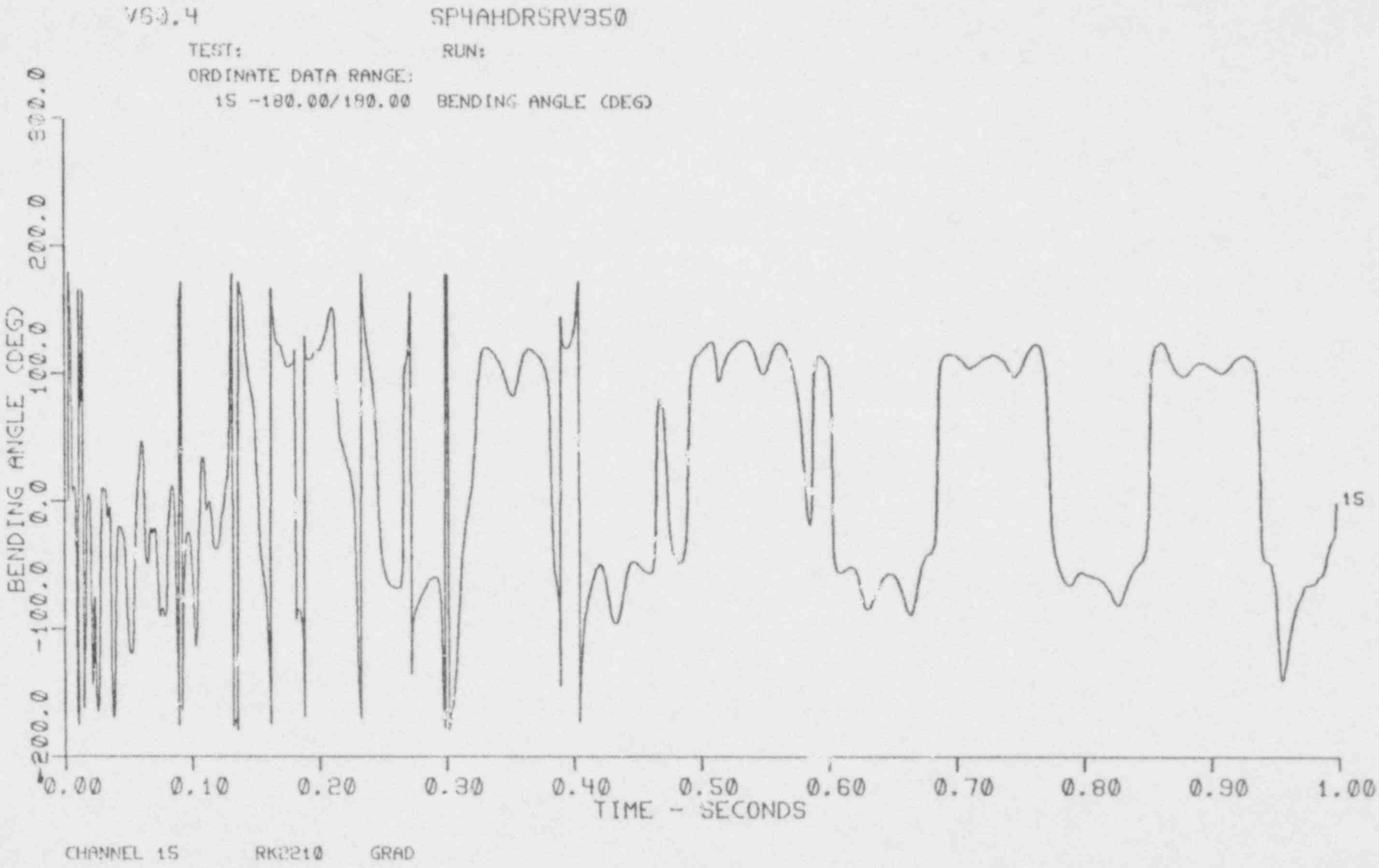

VS0.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
15 -180.00/180.00 BENDING ANGLE (DEG)
BENDING ANGLE (DEG)
300.0
200.0
100.0
0.0
-100.0
-200.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
15
CHANNEL 15
RK2210
GRAD

FIGURE 5.16

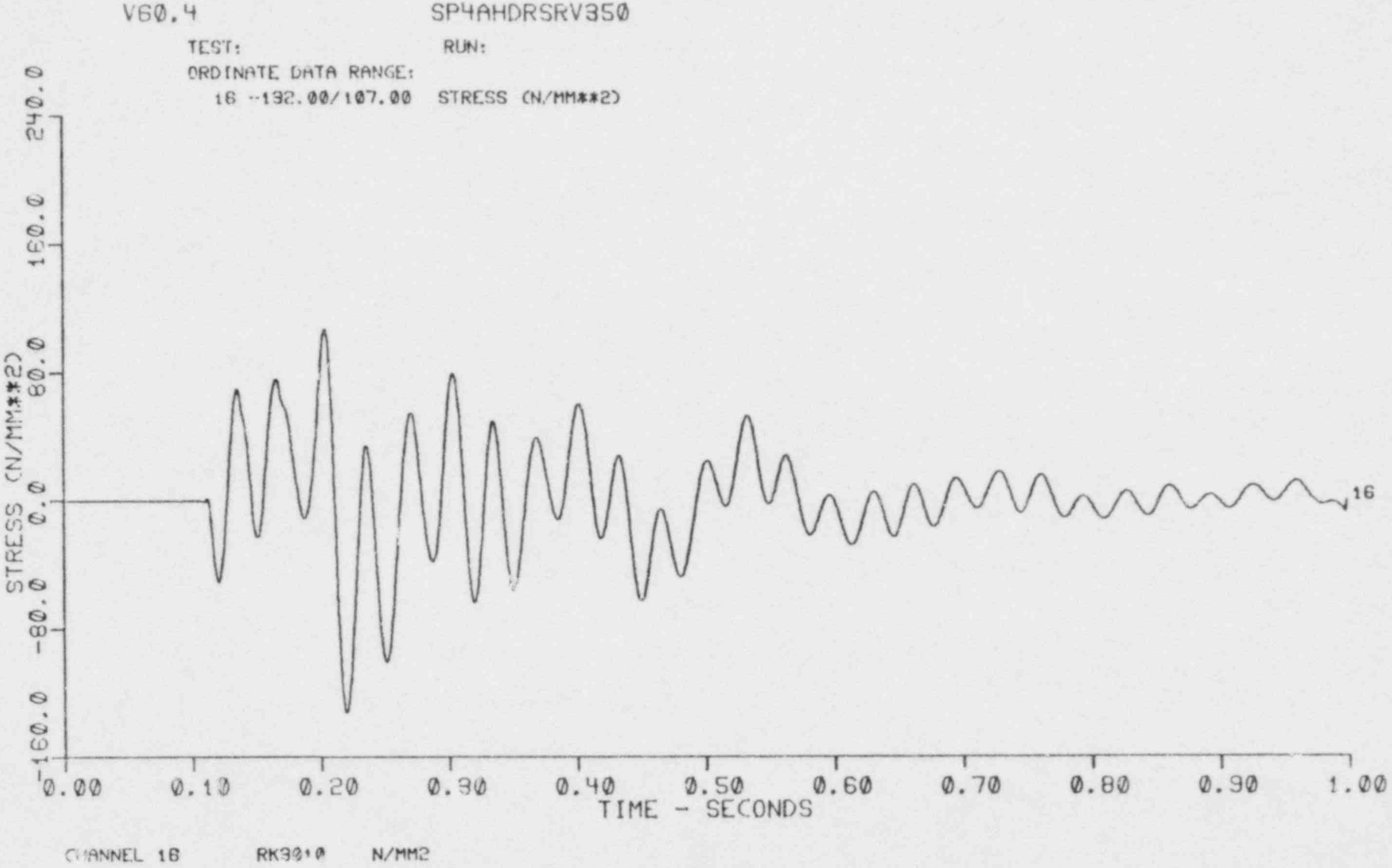

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
16 -132.00/107.00 STRESS (N/MM**2)
STRESS (N/MM**2)
240.0
160.0
80.0
0.0
-80.0
-160.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
16
CHANNEL 16
RK30:0
N/MM2

FIGURE 5.17

(RK 4110 not computed)

FIGURE 5.18

(RK 5010 not computed)

FIGURE 5.19

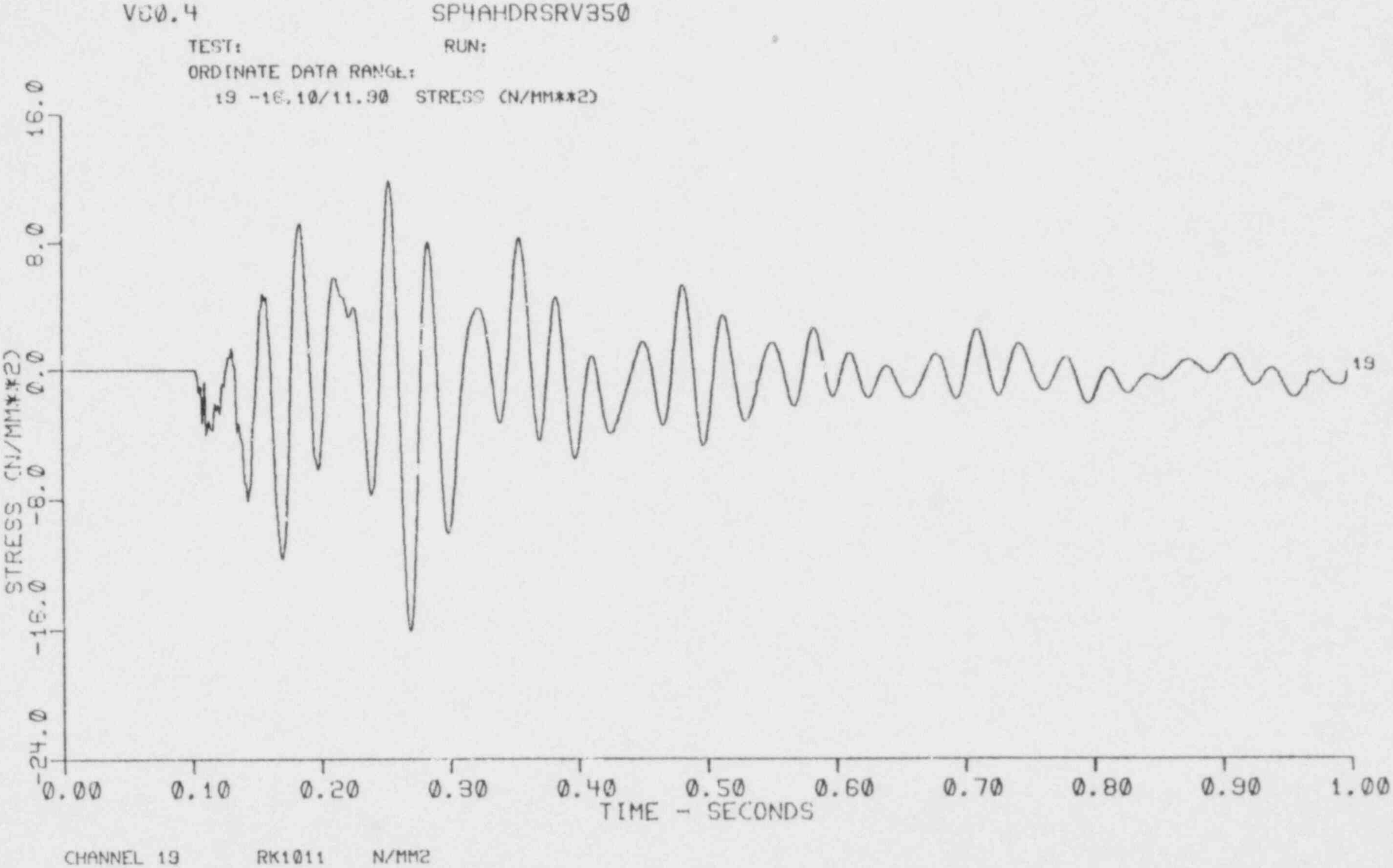

VC0.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
19 -16.10/11.90 STRESS (N/MM**2)
STRESS (N/MM**2)
16.0
8.0
0.0
-8.0
-16.0
-24.0
19
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 19
RK1011
N/MM2

FIGURE 5.20

(Problem with File Information for RK 2011)

FIGURE 5.21

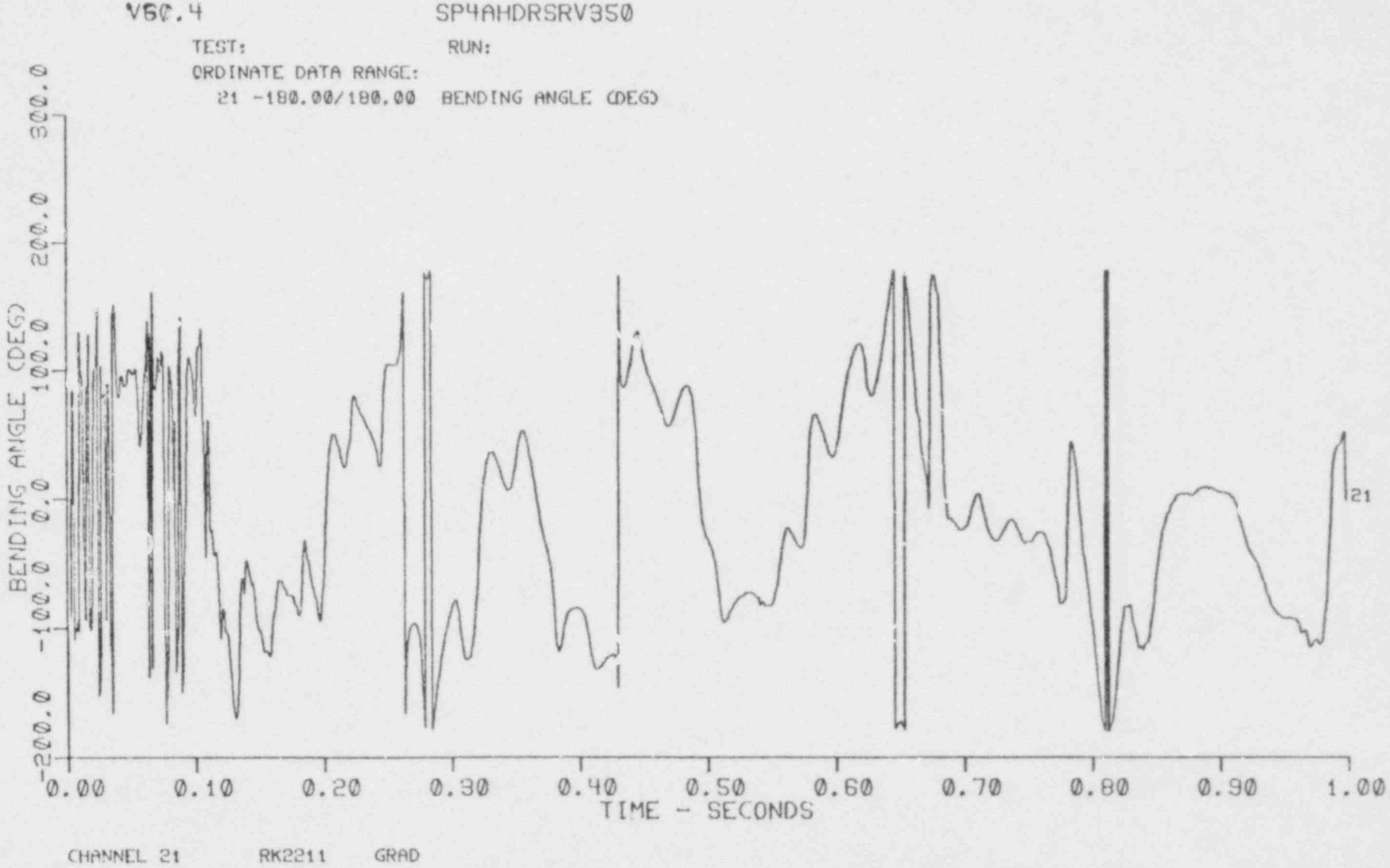

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
21 -180.00/180.00 BENDING ANGLE (DEG)
300.0
200.0
100.0
0.0
-100.0
-200.0
BENDING ANGLE (DEG)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
21
CHANNEL 21
RK2211
GRAD

FIGURE 5.22

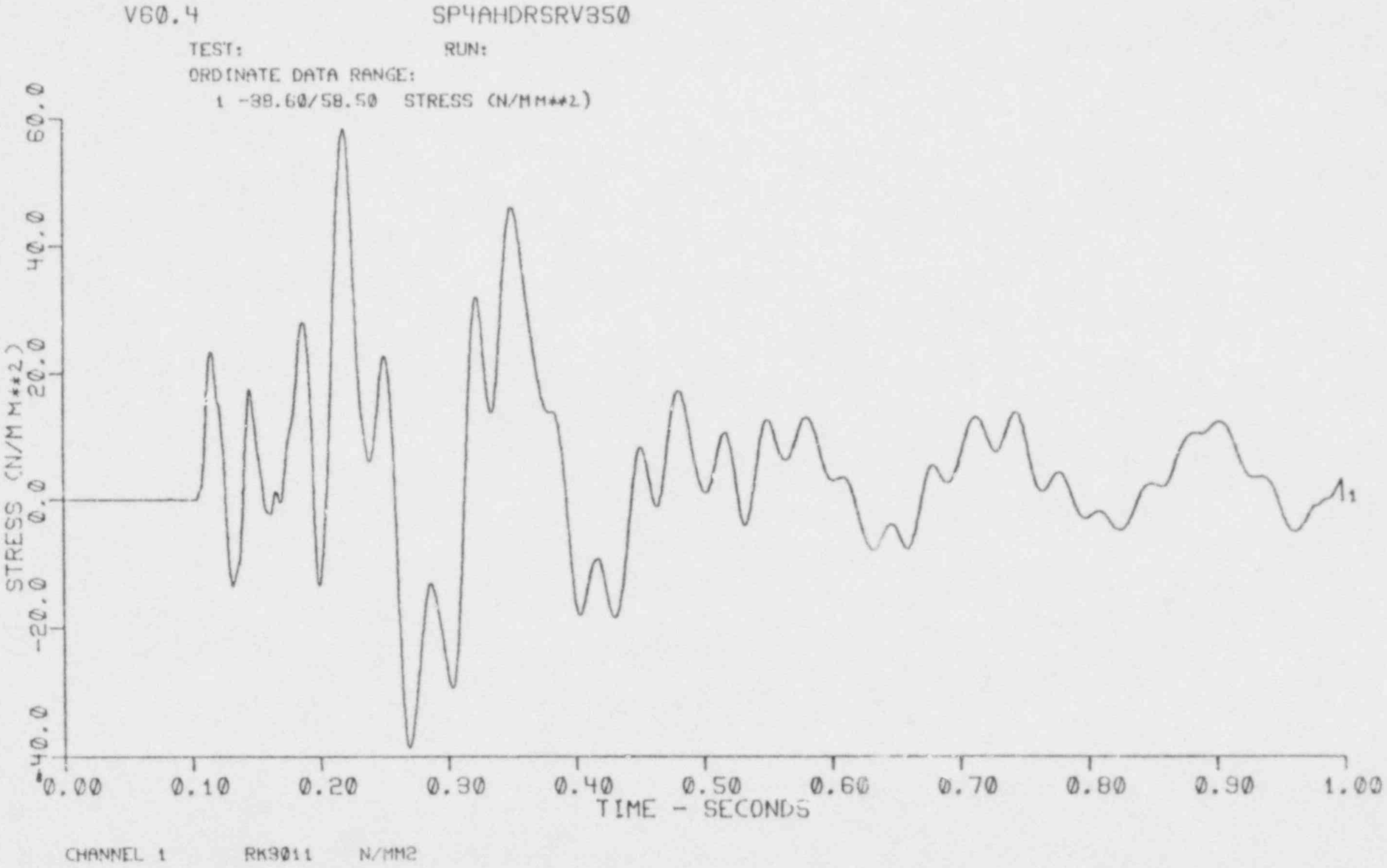

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
1 -38.60/58.50 STRESS (N/MM**2)
STRESS (N/M M**2)
60.0
40.0
20.0
0.0
-20.0
-40.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
1
CHANNEL 1
RK3011
N/MM2

FIGURE 5.23

(RK 4111 not computed)

FIGURE 5.24

(RK 5011 not computed)

FIGURE 5.25

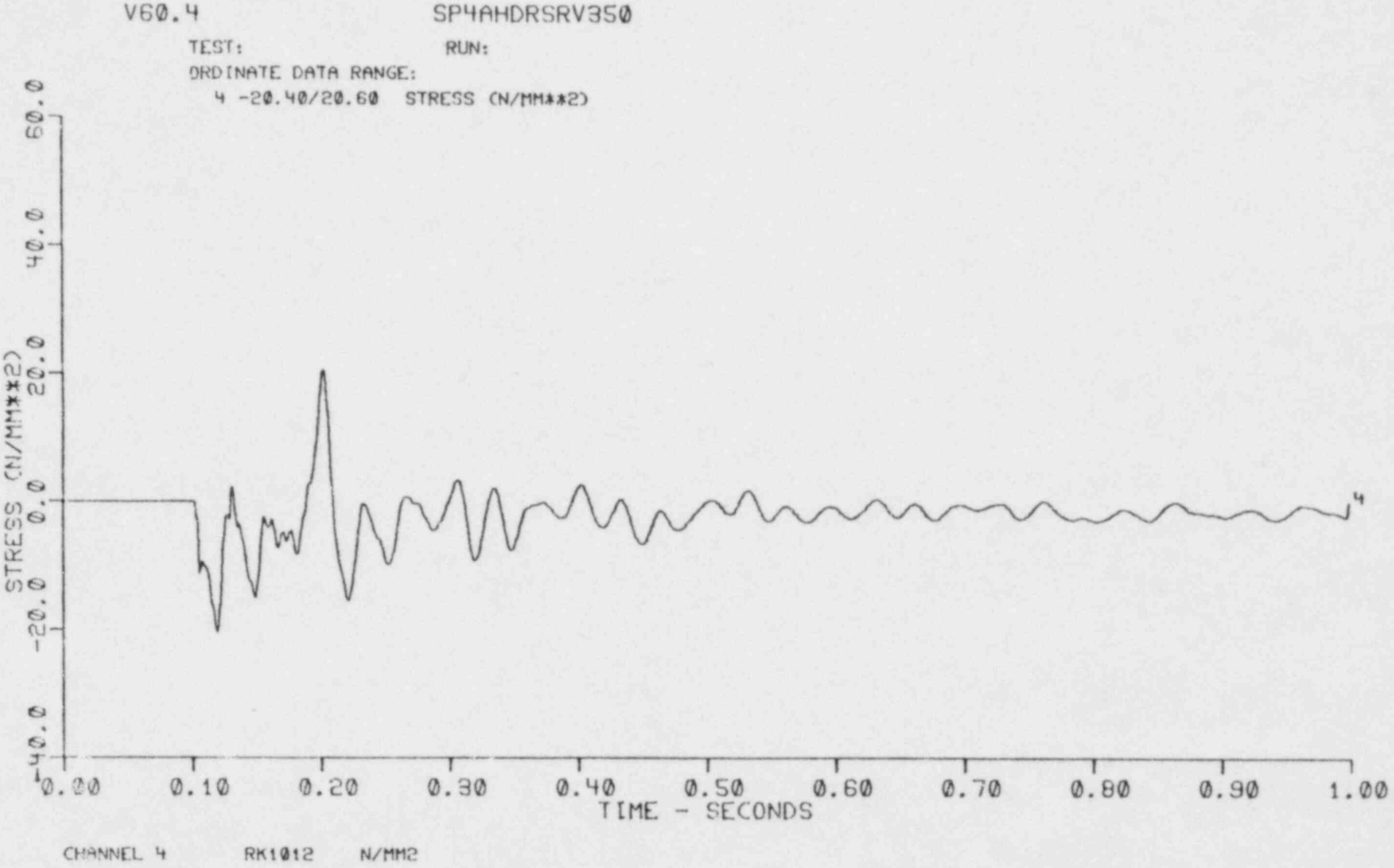

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
4 -20.40/20.60 STRESS (N/MM**2)
STRESS (N/MM**2)
60.0
40.0
20.0
0.0
-20.0
-40.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
4
CHANNEL 4
RK1012
N/MM2

FIGURE 5.26

(Problem with file information for RK 2012)

FIGURE 5.27

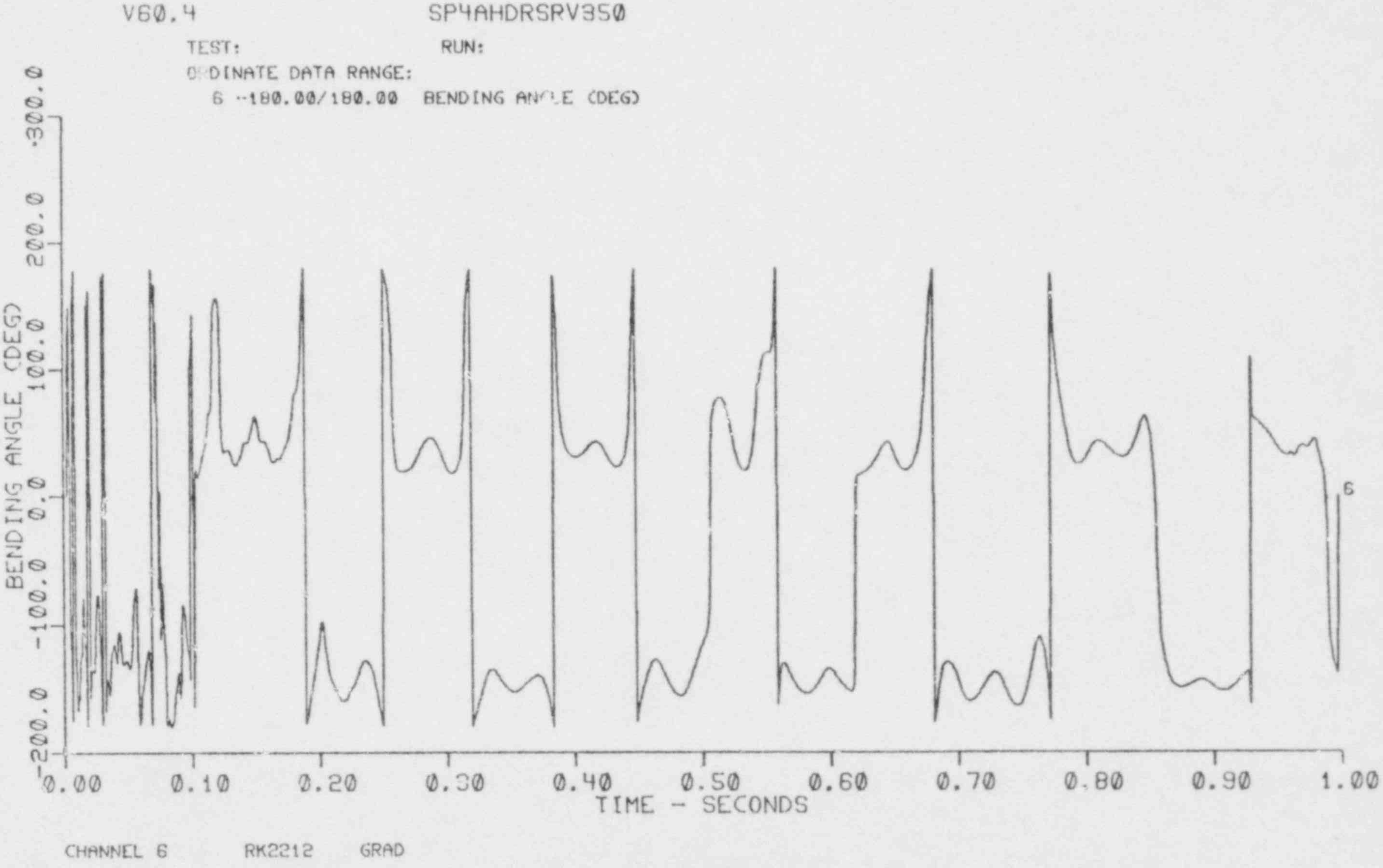

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
6 -180.00/180.00 BENDING ANGLE (DEG)
-300.0
200.0
100.0
0.0
-100.0
-200.0
BENDING ANGLE (DEG)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
6
CHANNEL 6
RK2212
GRAD

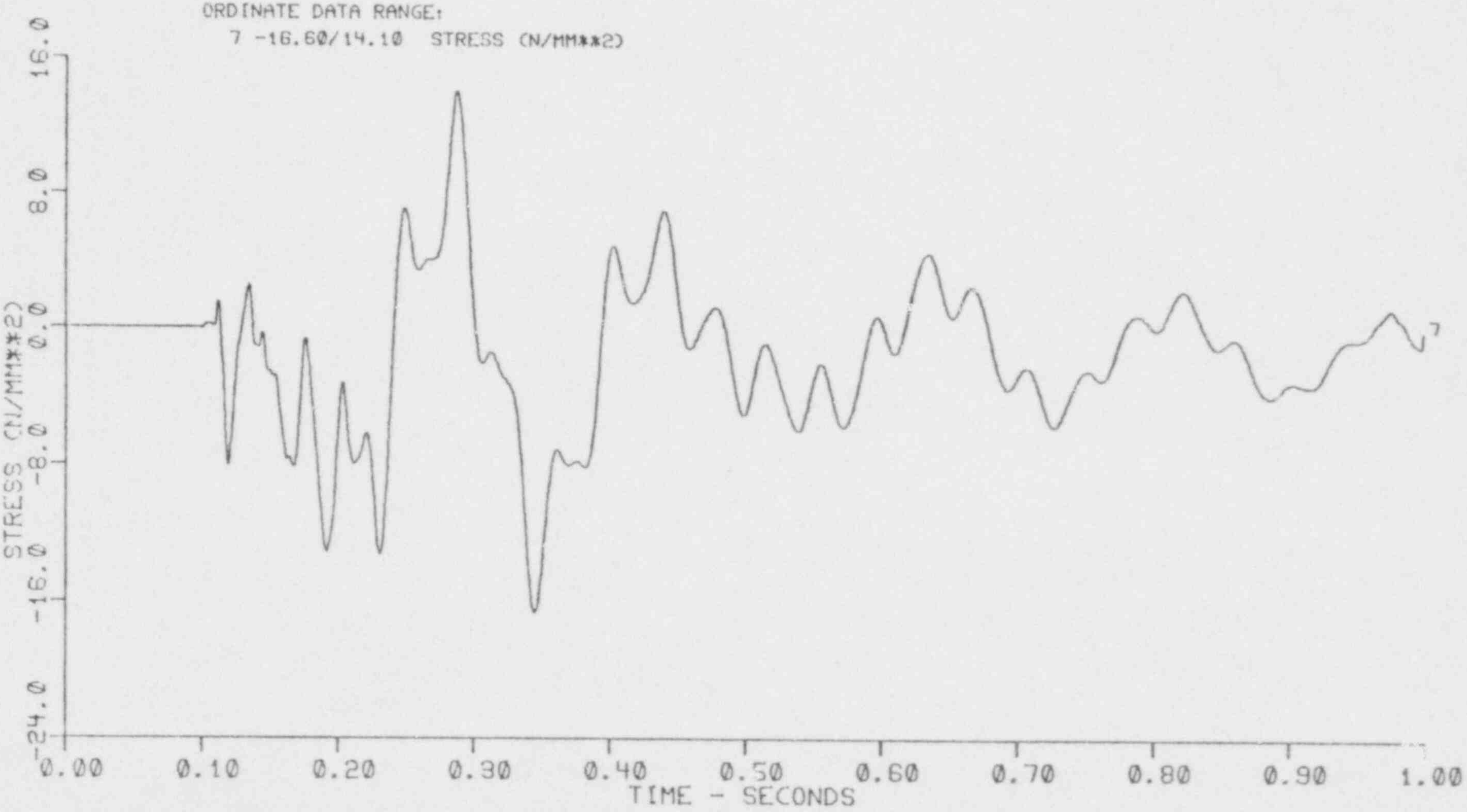
FIGURE 5.28

V60.4 SP4AHDRSRV350

TEST: RUN:

ORDINATE DATA RANGE:

7 -16.60/14.10 STRESS (N/MM**2)



CHANNEL 7 RK3012 N/MM2

FIGURE 5.29

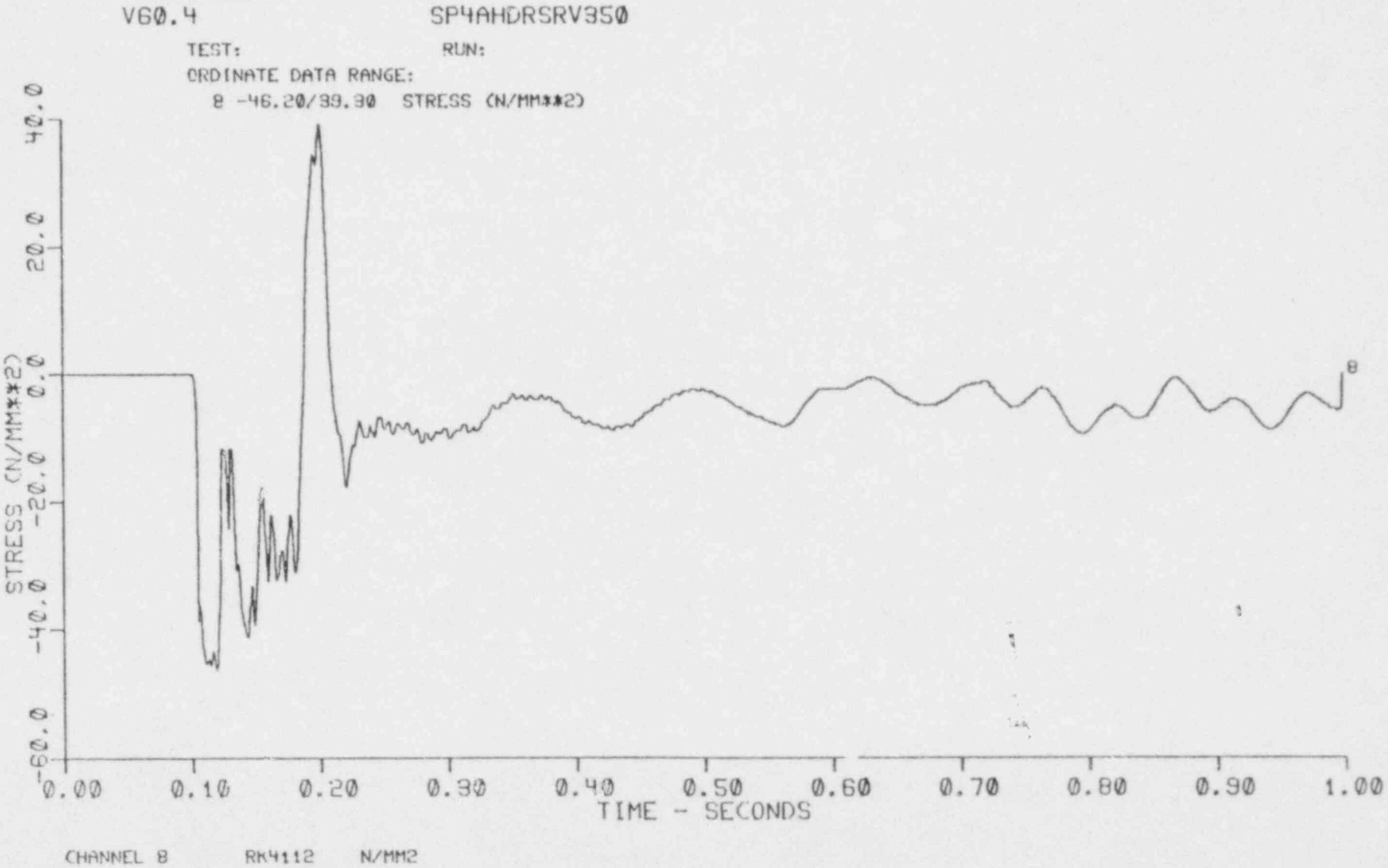

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
8 -46.20/39.90 STRESS (N/MM**2)
40.0
20.0
0.0
-20.0
-40.0
-60.0
STRESS (N/MM**2)
8
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 8
RK4112
N/MM2

FIGURE 5.30

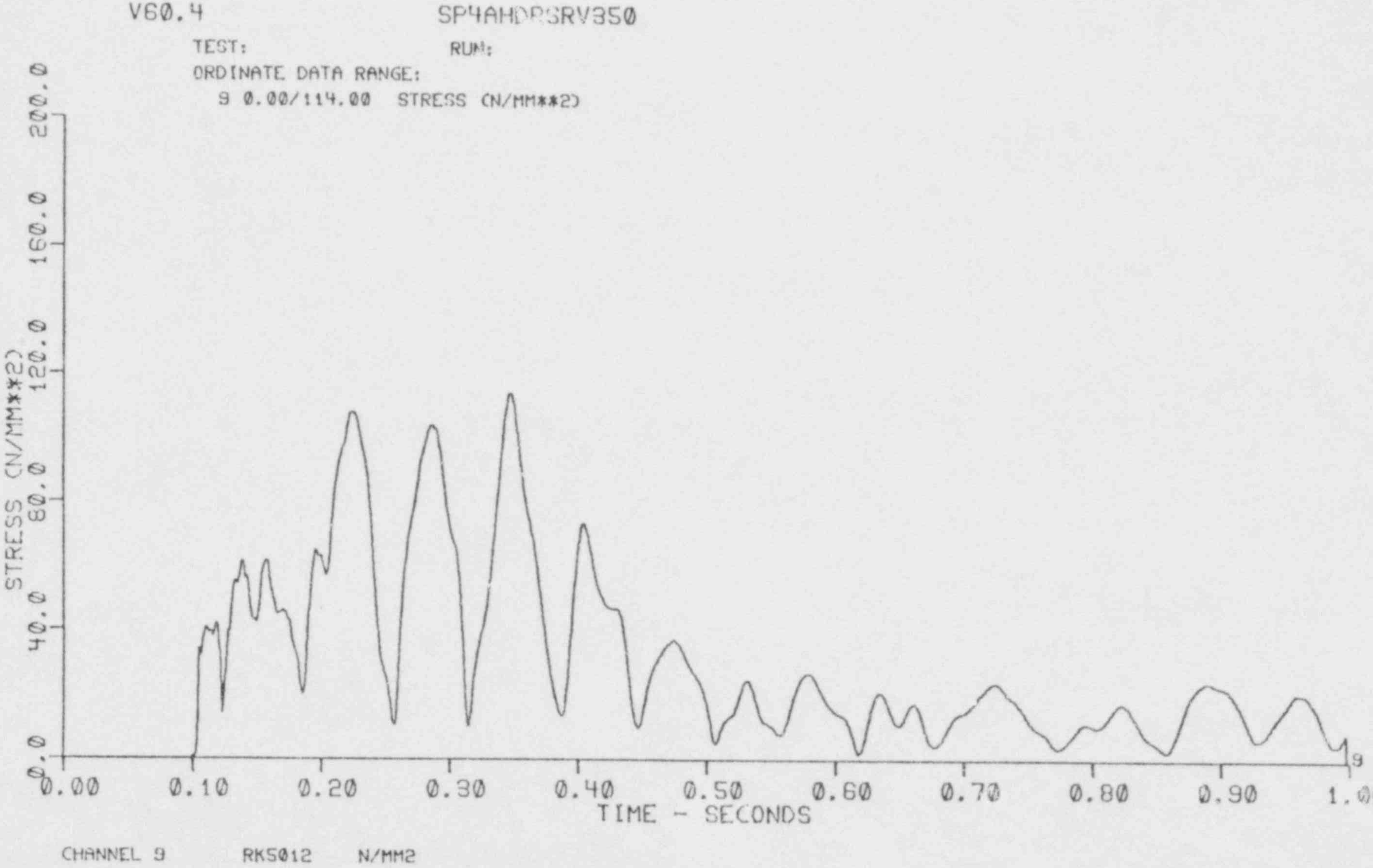

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
9 0.00/114.00 STRESS (N/MM**2)
STRESS (N/MM**2)
0.0
40.0
80.0
120.0
160.0
200.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
9
CHANNEL 9
RK5012
N/MM2

FIGURE 5.31

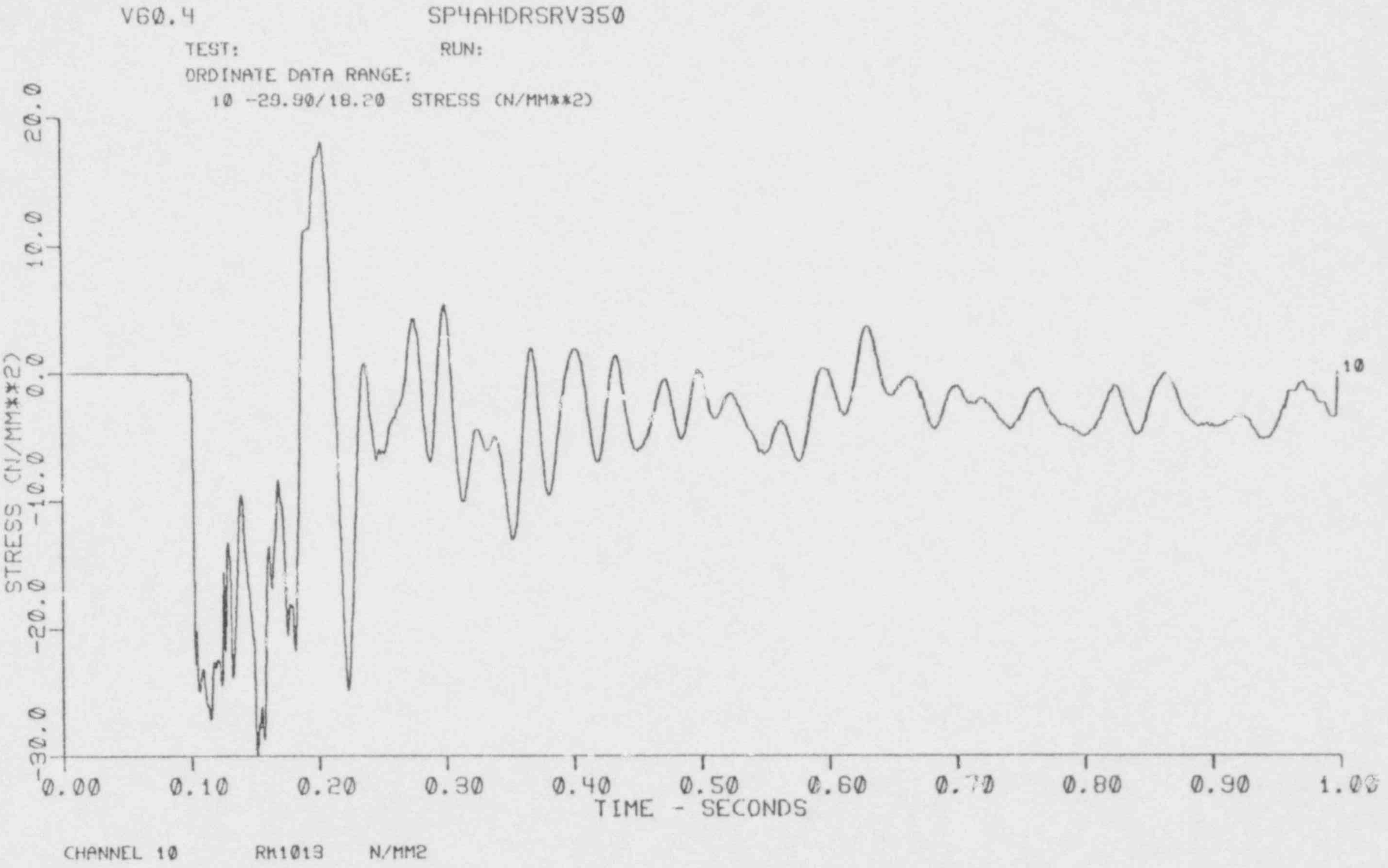

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
10 -29.90/18.20 STRESS (N/MM**2)
STRESS (N/MM**2)
20.0
10.0
0.0
-10.0
-20.0
-30.0
10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 10
RM1013
N/MM2

FIGURE 5.32

(Problem with file information for RK 2013)

FIGURE 5.33

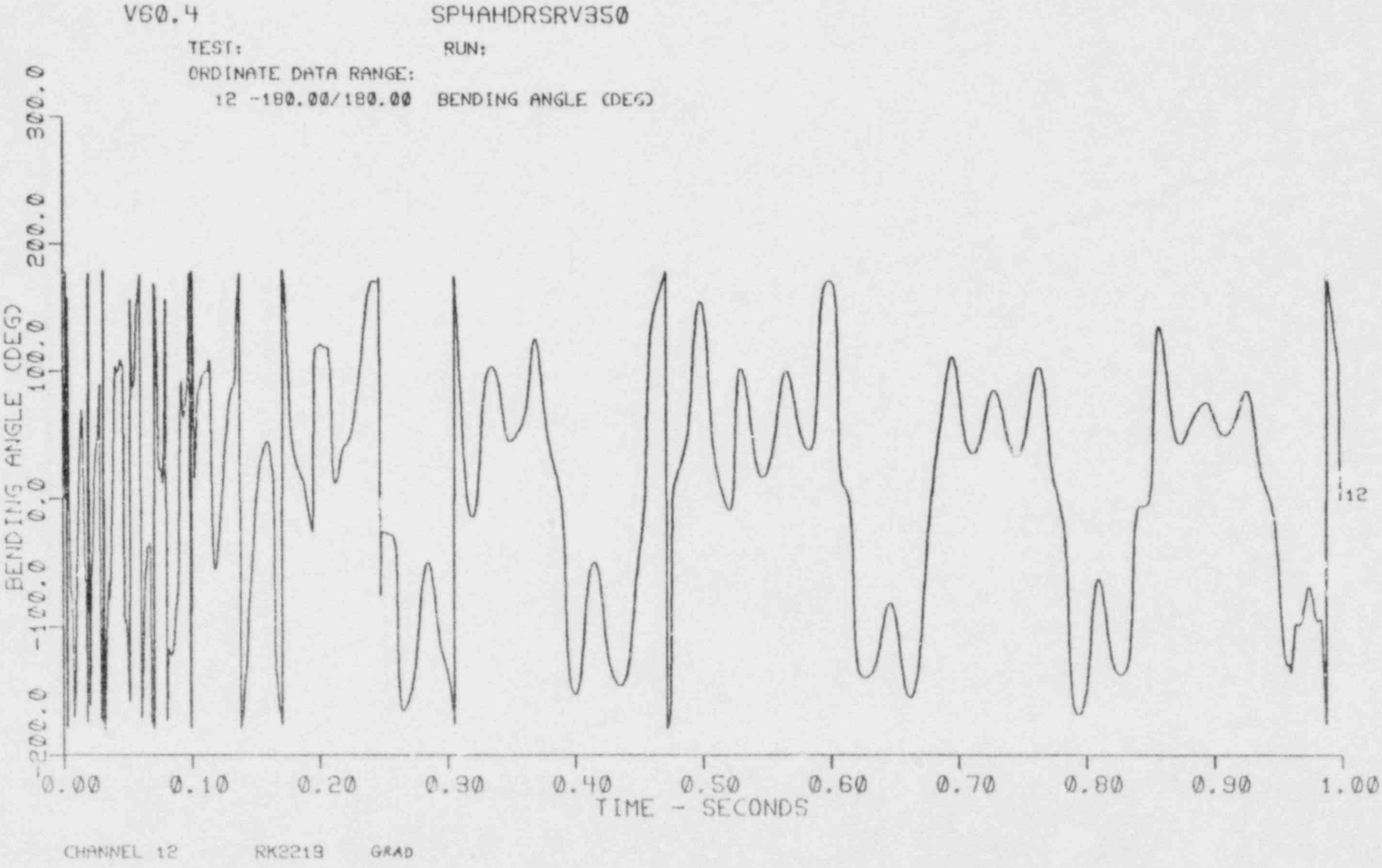

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
12 -180.00/180.00 BENDING ANGLE (DEG)
BENDING ANGLE (DEG)
300.0
200.0
100.0
0.0
-100.0
-200.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
12
CHANNEL 12
RK2213
GRAD

FIGURE 5.34

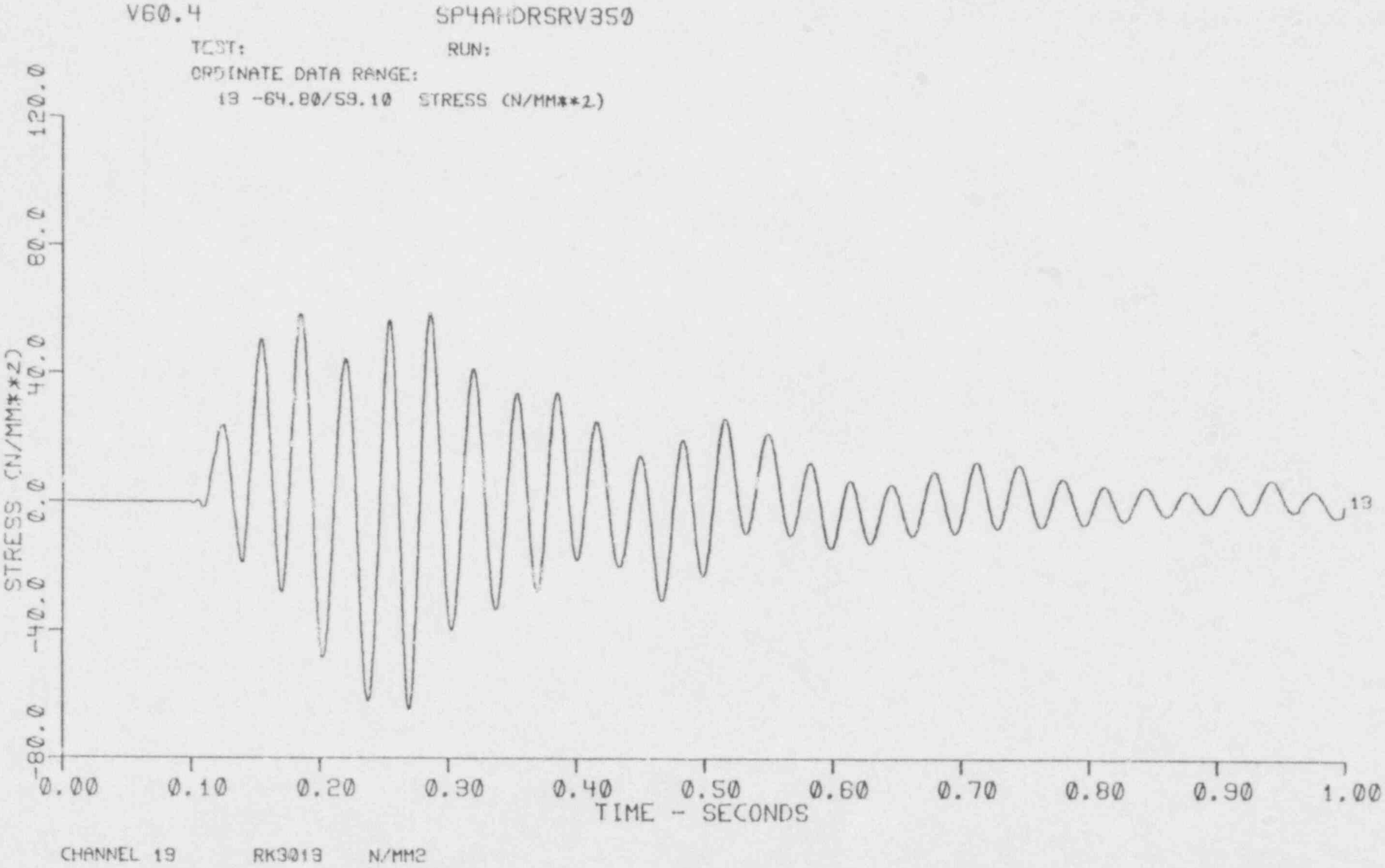

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
13 -64.80/59.10 STRESS (N/MM**2)
120.0
80.0
40.0
0.0
-40.0
-80.0
STRESS (N/MM**2)
13
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 13
RK3013
N/MM2

FIGURE 5.35

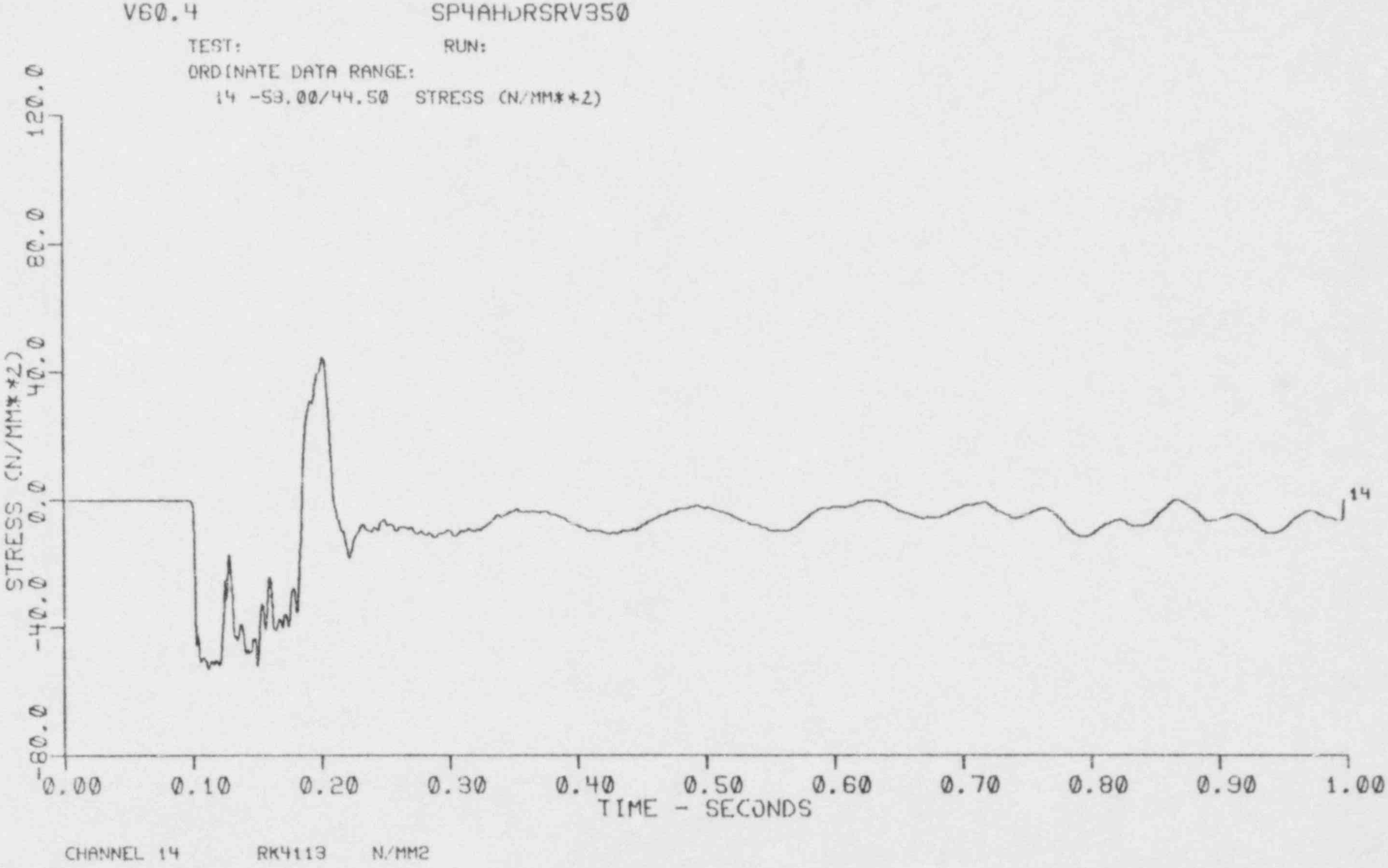
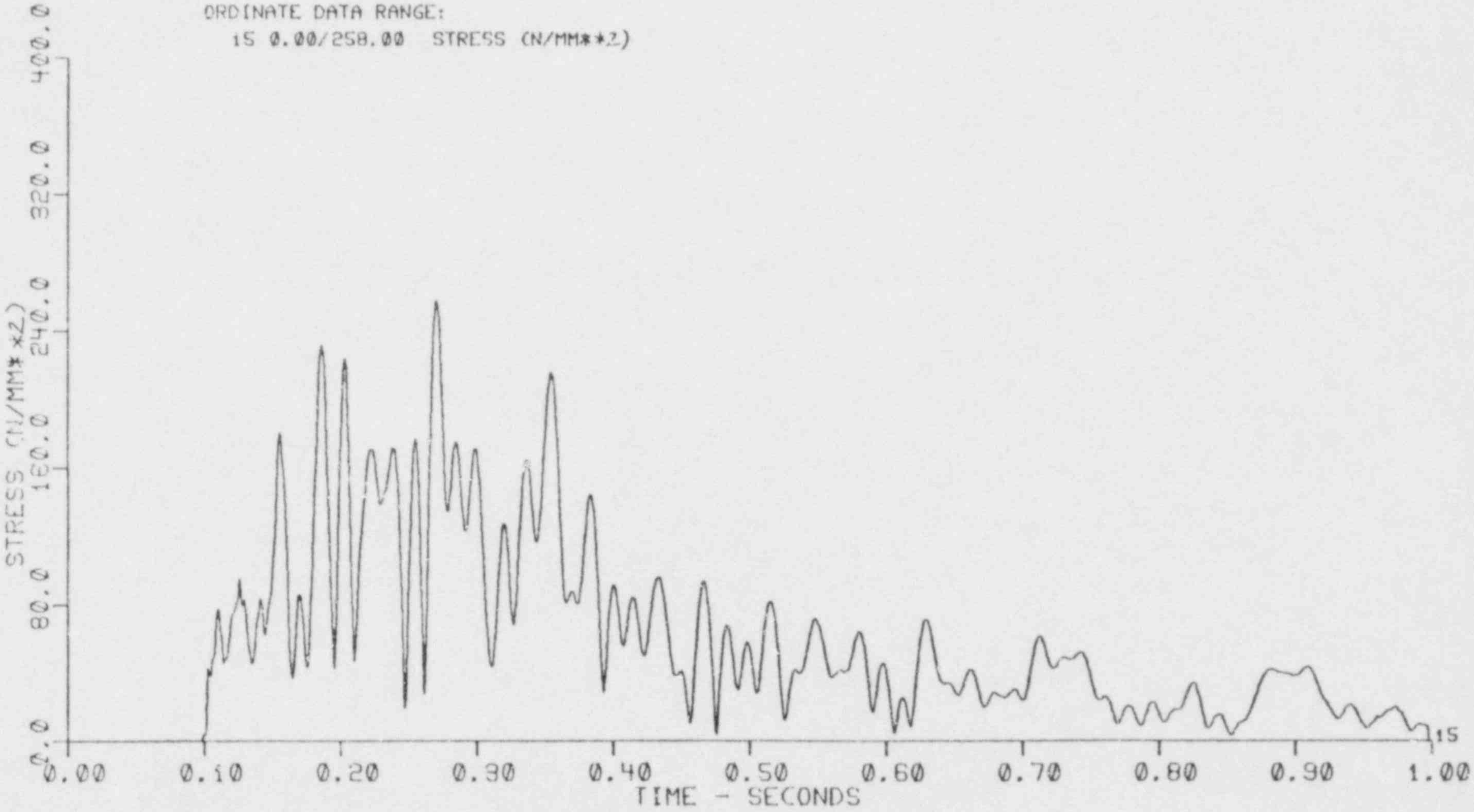

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
14 -53.00/44.50 STRESS (N/MM**2)
STRESS (N/MM**2)
120.0
80.0
40.0
0.0
-40.0
-80.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
14
CHANNEL 14
RK4113
N/MM2

FIGURE 5.36

V60.4 SP4AHDRSRV350

TEST: RUN:

ORDINATE DATA RANGE:
15 0.00/258.00 STRESS (N/MM**2)



CHANNEL 15 RK5013 N/MM2

FIGURE 5.37

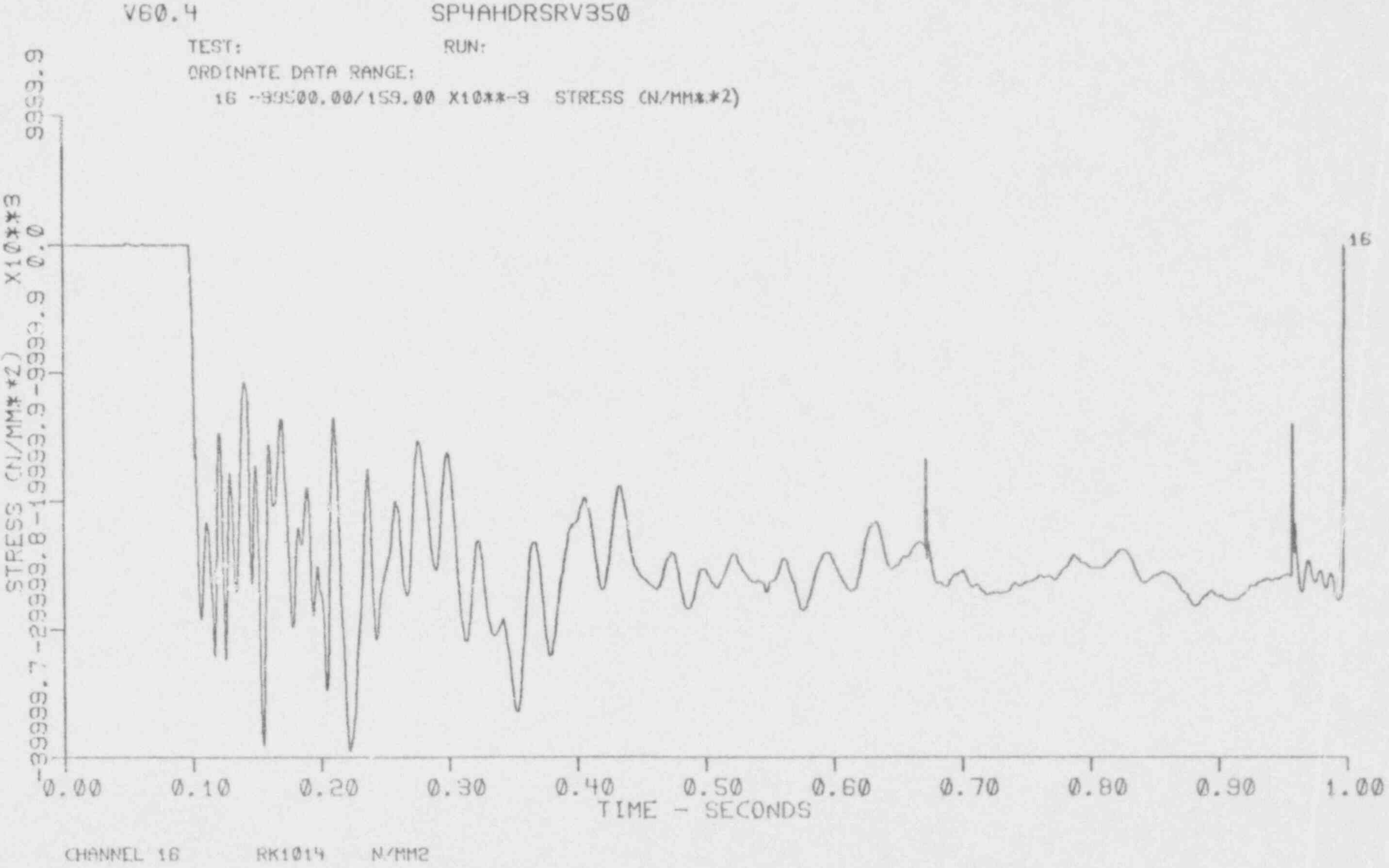

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
16 -39500.00/159.00 X10**-3 STRESS (N/MM**2)
STRESS (N/MM**2) X10**3
-39999.7
-29999.8
-19999.9
-9999.9
0.0
9999.9
16
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 16
RK1014
N/MM2

FIGURE 5.38

(Problem with file information for RK 2014)

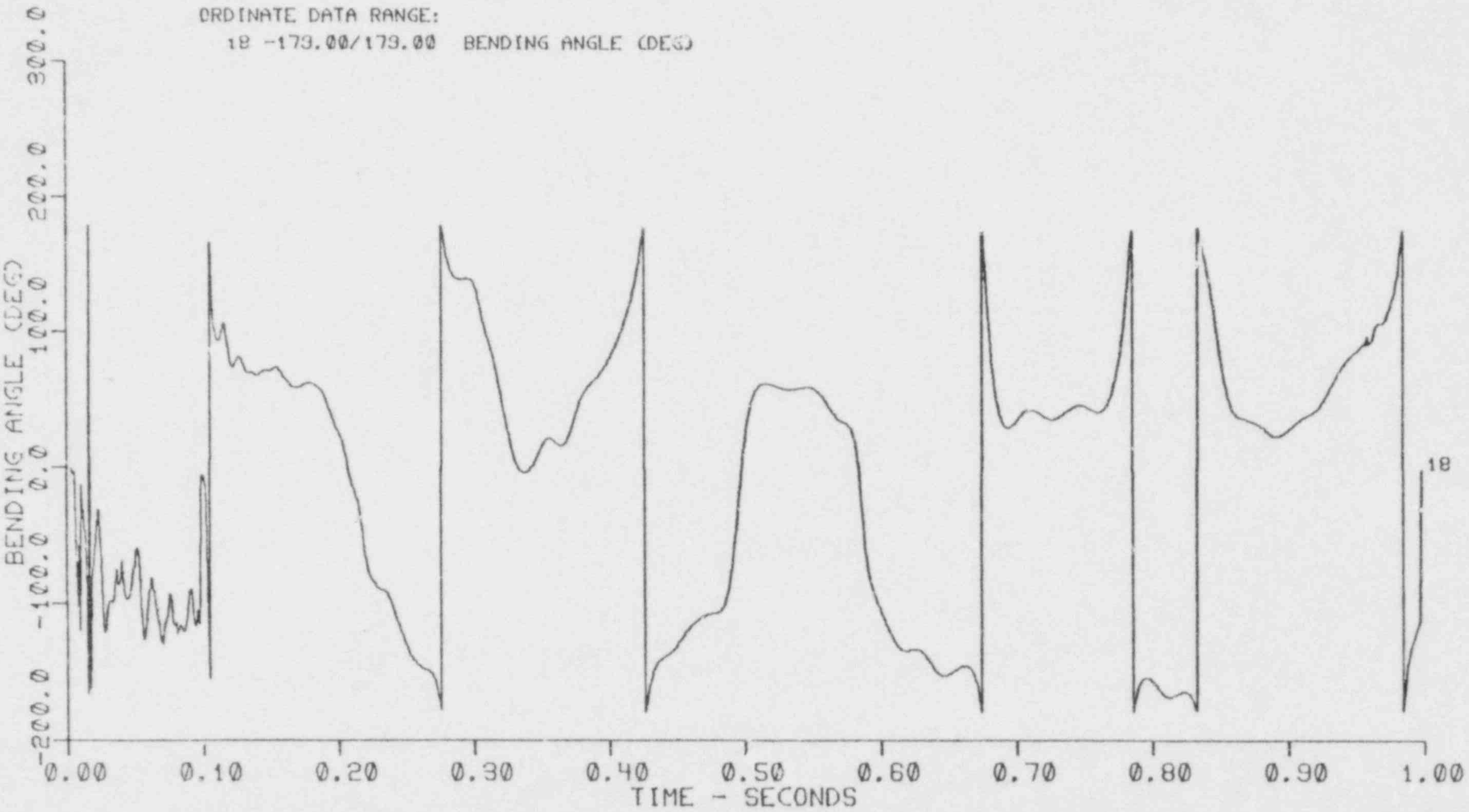
FIGURE 5.39

V60.4 SP4AHDRSRV350

TEST: RUN:

ORDINATE DATA RANGE:

18 -173.00/173.00 BENDING ANGLE (DEG)



CHANNEL 18 RK2214 *GRAD*

FIGURE 5.40

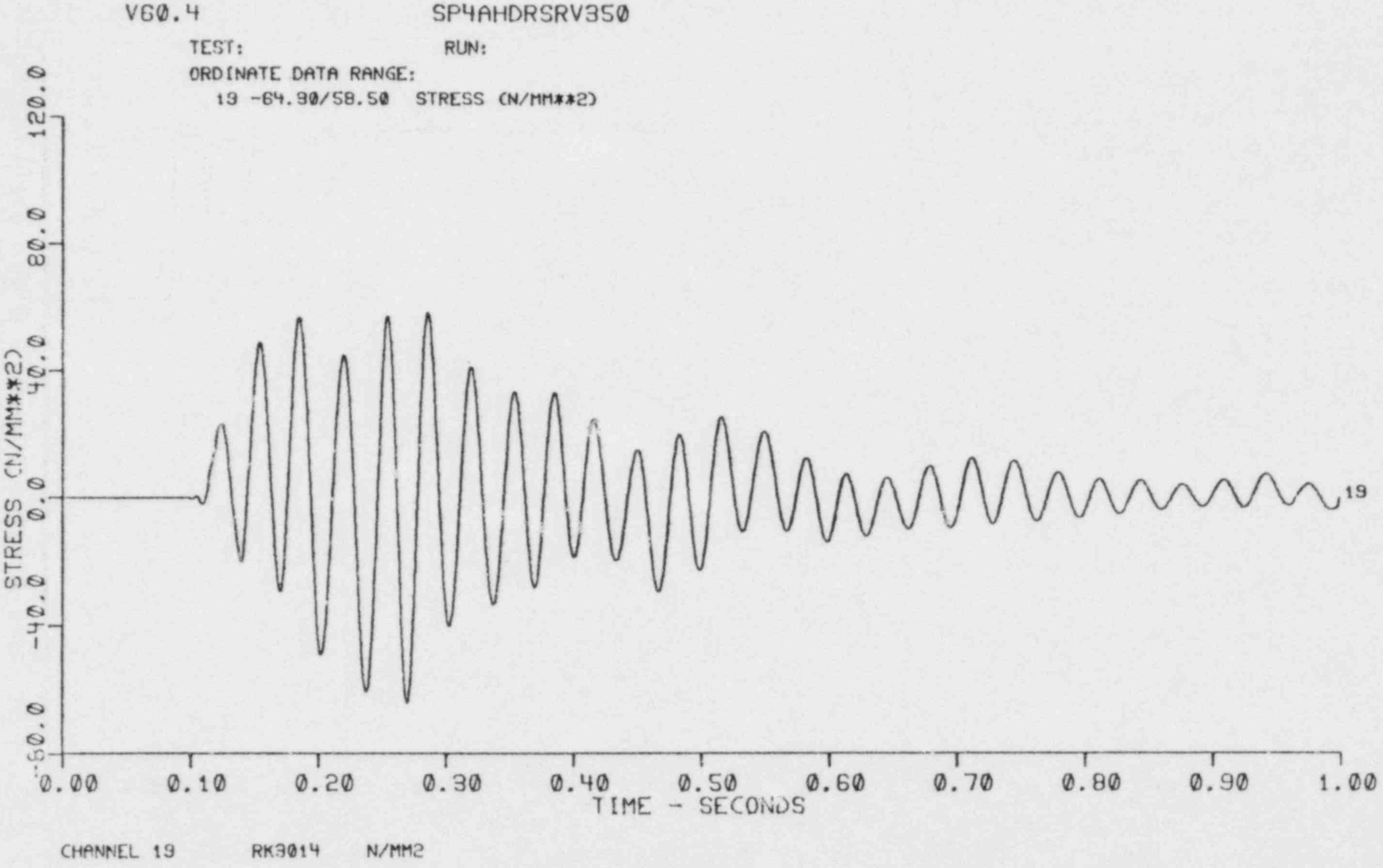

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
19 -64.90/58.50 STRESS (N/MM**2)
120.0
80.0
40.0
0.0
-40.0
-80.0
STRESS (N/MM**2)
19
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
CHANNEL 19
RK3014
N/MM2

FIGURE 5.41

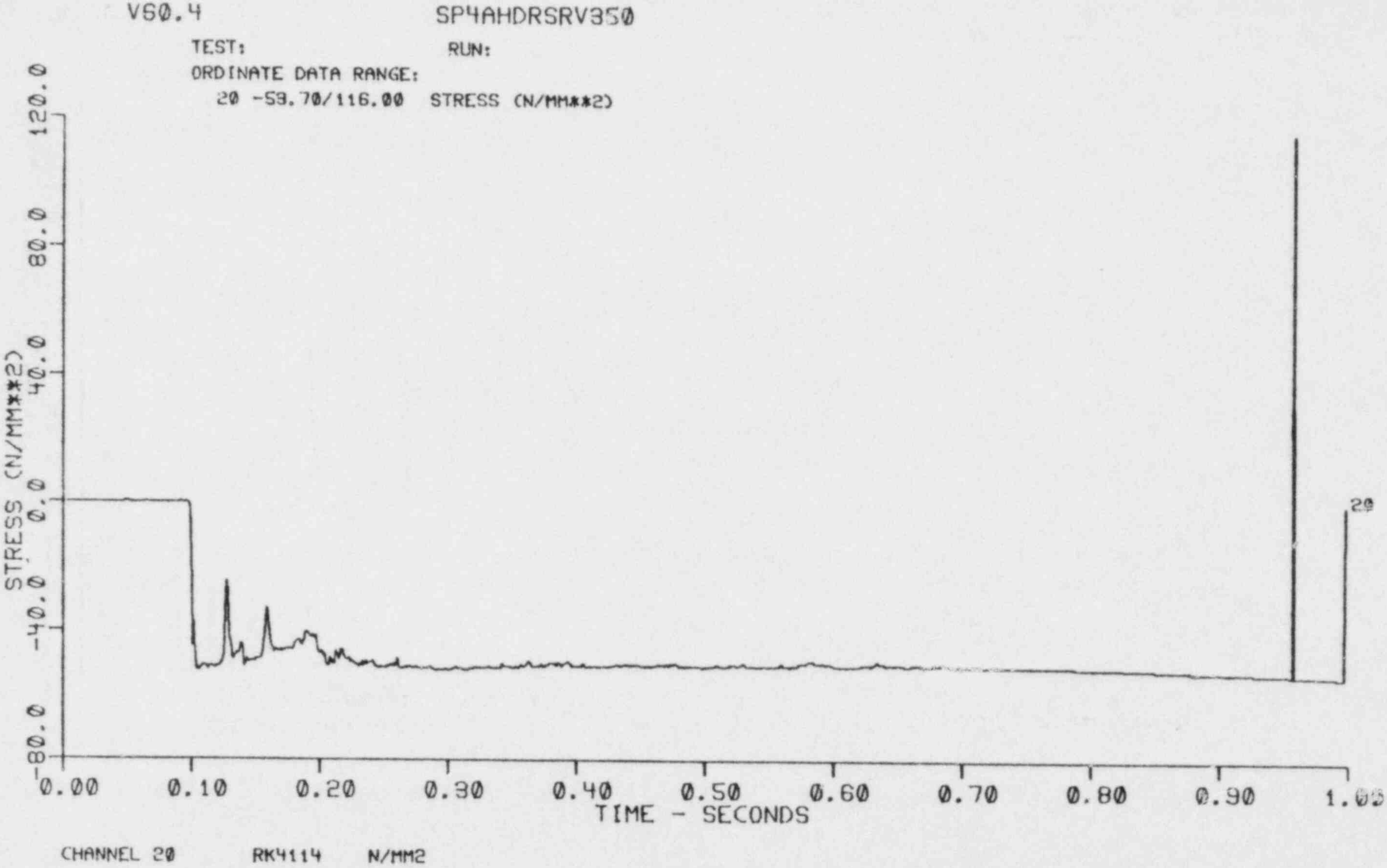

VS0.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
20 -53.70/116.00 STRESS (N/MM**2)
STRESS (N/MM**2)
120.0
80.0
40.0
0.0
-40.0
-80.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
20
CHANNEL 20
RK4114
N/MM2

FIGURE 5.42

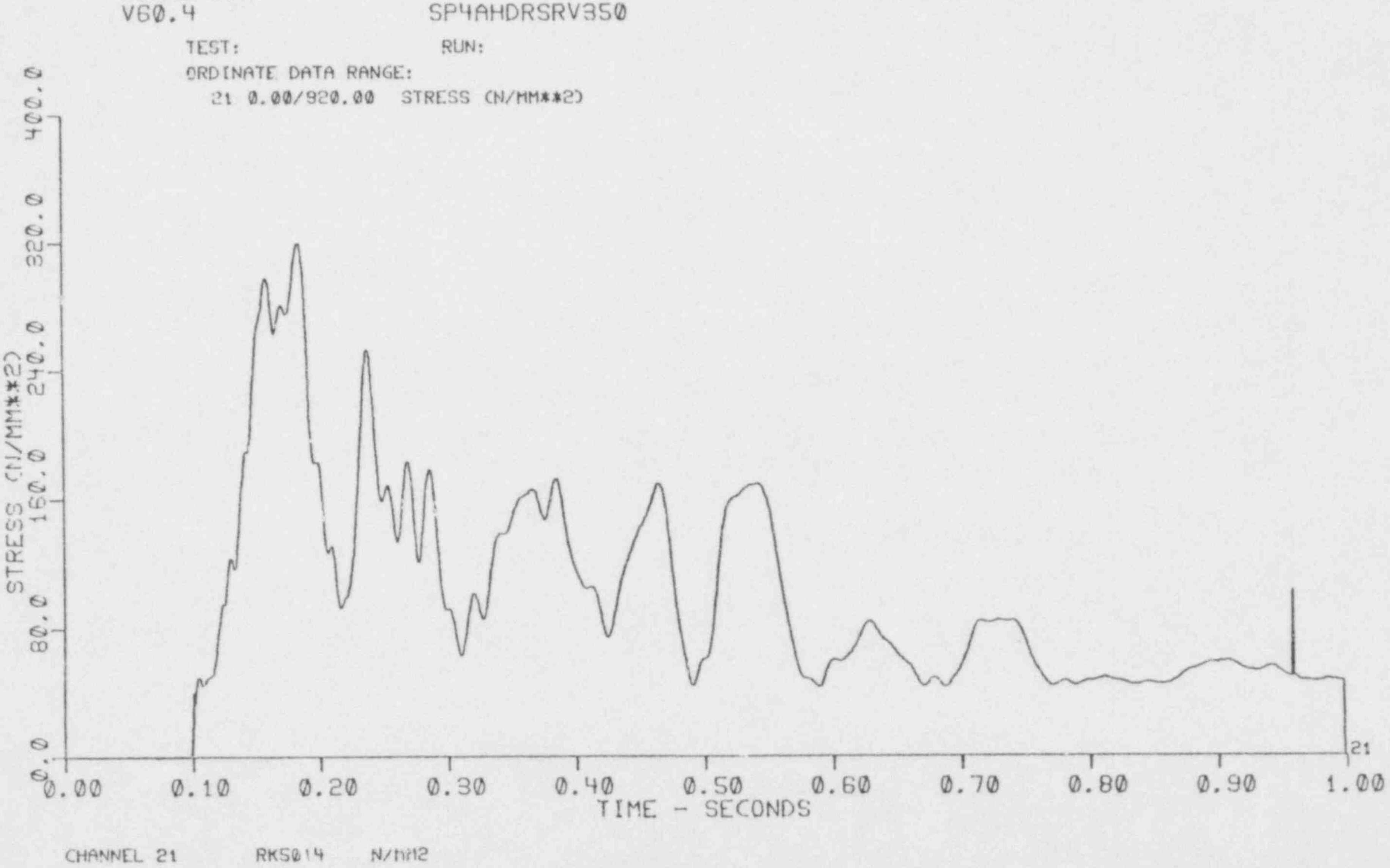

V60.4
SP4AHDRSRV350
TEST:
RUN:
ORDINATE DATA RANGE:
21 0.00/920.00 STRESS (N/MM**2)
STRESS (N/MM**2)
400.0
320.0
240.0
160.0
80.0
0.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
TIME - SECONDS
21
CHANNEL 21
RK5014
N/MM2

TABLE 5.1

EXTREME VALUES OF STRUCTURAL RESPONSE DISPLACEMENTS AND ACCELERATIONS

Response Number	ANCO Node	Response Direction	Minimum/Maximum Value
RS2201	14	y	-49/44 (mm)
RS2202	14	x	-20/20 (mm)
RS2203	14	z	-47/43 (mm)
RS2204	22	y	-87/67 (mm)
RS2205	22	z	-39/43 (mm)
RS2206	22	x	-50/41 (mm)
SS4004	43	z	-18/21 (mm)
SS4005	43	x	-1/2 (mm)
SS4006	43	y	-15/18 (mm)
SS4001	42	x	-38/7 (g's)
SS4002	42	y	-23/26 (g's)
SS4003	42	z	-19/18 (g's)

6.0 COMPARISON OF STRUCTURAL RESPONSE TEST DATA AND ANCO SIMULATION RESULTS

A brief comparison is made, herein, between some of the test data and the results of the simulation performed by ANCO Engineers, Inc. The quantities that have been compared are: (1) eigenvalues of the pipe system and; (2) maximum and minimum displacements of the pipe during the dynamic event. The test data was taken from the report "Ergebnisbericht, Blowndown-Versuch NR. V60.4.1, am 5.12.80, Versuchsgruppe SRV 350," Februar 1981, Kernforschungszentrum Karlsruhe, Projeckt HDR.

The experimentally determined and predicted eigenfrequencies are given in Table 6.1. There was a problem in comparing the two sets of values. Only two experimental frequencies were given below 25 Hz, whereas, there were three predicted frequencies. This difference was partially resolved through the following discussion. There is a large relative difference between the third and fourth theoretical eigenfrequencies. There is also a large difference between the second and fourth experimental eigenfrequencies (as defined in Table 6.1). Because of this, together with the fact that the values of the frequencies (experimental and predicted), as given for the fourth and fifth modes, are close to each other, it is believed that the experimental frequencies given in Table 6.1 for the fourth and fifth modes probably correspond to the fourth and fifth theoretical frequencies.

In comparing the eigenfrequencies below 25 Hz, there are essentially two possibilities. First, that there exist only two experimental frequencies below 25 Hz; or second, that there exist more experimental frequencies below 25 Hz, one of which was not detected during data analysis. Regardless of what the situation is, it is most logical that the first experimental frequency corresponds to the first theoretical frequency. If it did not, the first experimental frequency would correspond to the second theoretical frequency giving the theoretical frequency a relative error of 73 percent. With good agreement between theory and experiment for the fourth and fifth eigenfrequencies, and with the physical system being

TABLE 6.1
COMPARISON OF EXPERIMENTAL AND THEORETICAL EIGENFREQUENCIES

Mode	Experimental Eigenfrequency (Hz)	Predicted Eigenfrequency (Hz)	Relative Difference (%)
1	4.95	5.46	10.3
2	7.75	8.54	10.2
3	*	9.43	*
4	25.50	26.18	2.7
5	29.30	30.55	4.3

---

*Note: On the assumption that the first two experimental eigenfrequencies correspond to the first two theoretical eigenfrequencies, either there is not an experimental mode that corresponds to the third theoretical mode (9.43 Hz eigenfrequency mode) or the third experimental mode was not observed during analysis of the experimental data by German investigators.

essentially linear for non-plastic deformation and hence being very amenable to modeling as a linear system, an error of 73 percent for the second frequency is improbable. Overall, there seems to be excellent agreement between the two sets of eigenfrequencies.

The maximum and minimum displacements the pipe experienced during the dynamic test (DSP4) are compared to the predicted results in Table 6.2. There is a substantial difference between experiment and theory. Some of the large difference occurs where the displacement is small (i.e., SS4005) and, hence, does not have a great deal of meaning. Some of the large difference occurs where the displacement is large (i.e., RS2204). This difference is of concern. Some of the small to moderate differences occur where the displacements range from being small to large. Overall, the comparison of theory to experiment seems to be fair, with the predicted values bounding the experimental values.

TABLE 6.2
COMPARISON OF MAXIMUM AND MINIMUM DISPLACEMENTS

	Minimum/Maximum Value (mm)		
Transducer	Experimental	Predicted	Relative Difference (%)
RSS2202	-7/9	-20/20	186/122
RS2201	-35/37	-49/44	40/19
RS2203	-22/18	-47/43	114/139
RS2206	-/-	-50/41	-/-
RS2204	-52/62	-87/67	67/8
RS2205	(-30/30)*	-39/43	30/43
SS4005	-7/8	-1/2	85/75
SS4004	-23/27	-18/21	22/22
SS4006	-13/17	-15/18	15/6

---

*Note: Displacement transducer may have been damaged during the test.

7.0 COMMENTS

Even though the DSP4a theoretical simulation was to have been as close to reality as possible it was necessary to make certain simplifying assumptions due to reasonable resource constraints and limited fluid dynamic response data from DSP4. Following is a list of these assumptions:

Structural Assumptions

- A linear structural simulation would give meaningful results.
- Each end of the pipe line was fixed.
- The pipe could be represented with pipe elements (essentially straight and curved beam elements); no ovaling of the pipe elbows would occur to any significant degree.
- The damping effects could be represented with proportional damping and the damping was between 3.0% and 4.5% of critical.
- The fluid-structure problem could be decoupled and still give reasonably correct results.

Fluid Assumptions

- The discretization of the space inside the URL pipe into the six defined control volumes (Figure 4.2) was fine enough to generate a satisfactory load distribution on the pipe.
- The net rate of momentum efflux from a control volume and the rate of change of momentum within a control volume can be neglected as compared to the fluid pressure surface force of the volume.
- Body forces are negligible.
- Choosing the geometric center of a control volume as the center of pressure will not seriously affect the results.
- No significant concentrated moments on the pipe would be generated by the control volumes.

The structural dynamic simulation was performed using the above assumptions. The response information required by DSP4a was generated. As far as can be determined by inspection of the simulation results, it appears that there are no serious problems with the solution approach or the solution.

APPENDIX A

URL BLOWDOWN FINITE ELEMENT MODEL
(EASE2 INPUT LISTING)

APPENDIX A

URL BLOWDOWN FINITE ELEMENT MODEL

(EASE2 Input Listing)

Following is a listing of the data which defines the EASE2 model of the URL blowdown pipe system.

```
                                                  E A S E 2   I N P U T


M A S T E R   C O N T R O L   P A R A M E T E R S

       HDR / URL   BLOWDOWN MODEL                                                                                      PAGE      1
                                                                                                                       24  MAR 81

MASTER ECHO PRINT CONTROL                  =  (      )         SPS    (CC    15)
  EQ. *, SUPPRESS ECHO PRINT IN ALL
         DATA SECTIONS

SOLUTION MODE CONTROL                      =  (     4)         IMODE  (CC 16-20)
  EQ. 1, STATIC SOLUTION
  EQ. 2, EIGENVALUE SOLUTION ONLY
  EQ. 3, TIME-HISTORY ANALYSIS USING
         MODE SUPERPOSITION
  EQ. 4, TIME HISTORY ANALYSIS USING
         DIRECT INTEGRATION
  EQ. 5, RESPONSE SPECTRUM ANALYSIS

STIFFNESS MATRIX RESTART CONTROL           =  (     0)         IRSTR1 (CC    24)
  EQ. 1, PROGRAM EXPECTS TO READ THE
         DECOMPOSED STIFFNESS MATRIX
         FROM DISK FILE TAPE12

EIGENVALUES/EIGENVECTORS RESTART CONTROL   =  (     0)         IRSTR2 (CC    25)
  EQ. 1, PROGRAM EXPECTS TO READ
         EIGENVALUES AND EIGENVECTORS
         FROM DISK FILE TAPE13

NODE RESEQUENCING CONTROL                  =  (     2)         IBAND  (CC 26-30)
  EQ. 0, INTERNAL NODE NUMBERS ASSIGNED
         IN ASCENDING NODE ORDER
  EQ. 1, INTERNAL NODE NUMBERS ASSIGNED
         SEQUENTIALLY AS NODES ARE
         ENCOUNTERED DURING INPUT
  EQ. 2, INTERNAL NODE NUMBERS ASSIGNED
         TO PRODUCE A REDUCED BANDWIDTH
         USING  *GPS*  ALGORITHM
  BLANK, DEFAULT SET TO 2

MAXIMUM CORE FOR EASE2 EXECUTION           =  (250000)         ICORE  (CC 35-40)
  BLANK, DEFAULT SET TO 250000
  LT. 100000B, RESET TO 100000B
```

```
C O O R D I N A T E   S Y S T E M   D A T A

      HDR / URL   BLOWDOWN MODEL                                                                                          PAGE     2
                                                                                                                          24  MAR 81

COORDINATE                                                      PROJECTIONS OF CARTESIAN    (X*)     PROJECTIONS OF CARTESIAN    (Y*)
  SYSTEM    SYSTEM        COORDINATES OF THE ORIGIN                      OR CYLINDRICAL (Z*)                  OR CYLINDRICAL (R*)
  NUMBER     TYPE      GLOBAL X  GLOBAL Y  GLOBAL Z              GLOBAL X  GLOBAL Y  GLOBAL Z          GLOBAL X  GLOBAL Y  GLOBAL Z

     2         0        -2.421    17.300      .650                  .259     0.000      .966              .966     0.000     -.259
     3         0        -2.170    17.300     1.253                  .500     0.000      .866              .866     0.000     -.500
     4         0        -1.832    17.300     2.373                 -.500     0.000      .866              .866     0.000      .500
     5         0        -2.846    16.765     4.130                 0.000    -1.000     0.000              .866     0.000      .500
     6         0        -3.374    11.500     3.325                 -.866     0.000     -.500             -.500     0.000      .866
     7         0        -2.506    17.300     -.520                 0.000     0.000     1.000             1.000     0.000     0.000
```

```
I N P U T   N O D E   D A T A

      HDR / URL   BLOWDOWN MODEL                                                                                          PAGE      3
                                                                                                                          24  MAR 81

                                                    ---   G E N E R A T I O N   ---
NODE SYSTEM  COORDINATES OF THE FIRST NODE THICK-               PERCENT  2ND-LEVEL     COORDINATES OF THE LAST NODE   NODE
  NO  /TYPE    X1-ORD    X2-ORD    X3-ORD    NESS  NUMBER  INC   CHANGE       CODE     X1-ORD     X2-ORD     X3-ORD  COUNT

   2   0/       0.000    17.300     0.000    0.00                                                                        1
   4   0/      -1.379    17.300     -.796    0.00                                                                        2
   6   0/      -1.703    17.300     -.984    0.00                                                                        3
   8   0/      -2.506    17.300     -.520    0.00                                                                        4
  10   0/      -2.506    17.300     0.000    0.00                                                                        5
  11   7/       1.170      .085     0.000    0.00                                                                        6
  12   0/      -2.170    17.300     1.253    0.00                                                                        7
  14   0/      -1.832    17.300     1.838    0.00                                                                        8
  16   0/      -1.832    17.300     2.373    0.00                                                                        9
  18   0/      -2.206    17.300     3.020    0.00                                                                       10
  20   0/      -2.579    17.300     3.667    0.00                                                                       11
  22   0/      -2.846    16.765     4.130    0.00                                                                       12
  24   0/      -2.846    15.834     4.130    0.00                                                                       13
  26   0/      -2.846    14.903     4.130    0.00                                                                       14
  28   0/      -2.846    13.971     4.130    0.00                                                                       15
  30   0/      -2.846    13.040     4.130    0.00                                                                       16
  32   0/      -2.846    12.550     4.130    0.00                                                                       17
  34   0/      -2.846    12.209     4.130    0.00                                                                       18
  36   0/      -2.846    12.109     4.130    0.00                                                                       19
  37   6/       -.431     0.000      .179    0.00                                                                       20
  38   0/      -3.374    11.500     3.825    0.00                                                                       21
  40   0/      -3.359    11.500     3.545    0.00                                                                       22
  42   0/      -4.275    11.500     3.305    0.00                                                                       23
  43   0/      -4.790    11.500     3.010    0.00                                                                       24
  44   0/      -5.314    11.500     2.705    0.00                                                                       25
  46   0/      -5.747    11.500     2.455    0.00                                                                       26
  48   0/      -5.920    11.500     2.358    0.00                                                                       27
  49   6/       3.250     -.084     0.000    0.00                                                                       28
  50   0/      -6.230    11.500     1.830    0.00                                                                       29
  52   0/      -6.287    11.500     1.308    0.00                                                                       30
```

```
O R D E R E D   N O D E   D A T A   (GLOBAL CARTESIAN COORDINATES)

      HDR / URL   BLOWDOWN MODEL                                                                                          PAGE     4
                                                                                                                          24  MAR 81
  NODE         GLOBAL      GLOBAL      GLOBAL  THICK-            NODE        GLOBAL      GLOBAL      GLOBAL  THICK-
NUMBER          X-ORD       Y-ORD       Z-ORD    NESS          NUMBER         X-ORD       Y-ORD       Z-ORD    NESS

     2         0.0000     17.3000      0.0000    0.00
     4        -1.3790     17.3000      -.7960    0.00
     6        -1.7030     17.3000      -.9840    0.00
     8        -2.5060     17.3000      -.5200    0.00
    10        -2.5060     17.3000      0.0000    0.00
    11        -2.4210     17.3000       .6500    0.00
    12        -2.1700     17.3000      1.2530    0.00
    14        -1.8320     17.3000      1.8380    0.00
    16        -1.8320     17.3000      2.3730    0.00
    18        -2.2060     17.3000      3.0200    0.00
    20        -2.5790     17.3000      3.6670    0.00
    22        -2.8460     16.7650      4.1300    0.00
    24        -2.8460     15.8340      4.1300    0.00
    26        -2.8460     14.9030      4.1300    0.00
    28        -2.8460     13.9710      4.1300    0.00
    30        -2.8460     13.0400      4.1300    0.00
    32        -2.8460     12.5500      4.1300    0.00
    34        -2.8460     12.2090      4.1300    0.00
    36        -2.8460     12.1090      4.1300    0.00
    37        -3.0007     11.6790      4.0405    0.00
    38        -3.3740     11.5000      3.8250    0.00
    40        -3.8590     11.5000      3.5450    0.00
    42        -4.2750     11.5000      3.3050    0.00
    43        -4.7900     11.5000      3.0100    0.00
    44        -5.3140     11.5000      2.7050    0.00
    46        -5.7470     11.5000      2.4550    0.00
    48        -5.9200     11.5000      2.3580    0.00
    49        -6.1466     11.5000      2.1272    0.00
    50        -6.2300     11.5000      1.8300    0.00
    52        -6.2870     11.5000      1.3080    0.00
```

```
R E S T R A I N E D   N O D E S

      HDR / URL   BLOWDOWN MODEL                                                                                           PAGE      5
                                                                                                                          24  MAR 81

GENERAL RESTRAINT CODE APPLIED TO ALL NODES    (000000)          SSCODE (CC 25-30)

   NODE     BOUNDARY    /TRANSLATIONAL COMPONENT VALUES/   / ROTATIONAL COMPONENT  VALUES /   G E N E R A T I O N    NODE
  NUMBER       CODES       (X OR R)    (Y OR S)    (Z OR T)      (X OR R)    (Y OR S)   (Z OR T)   NUMBER    INCREMENT    COUNT

       2     DDD DDD    0.          0.          0.            0.          0.          0.                0            1        1
       4     DDD DDD    0.          0.          0.            0.          0.          0.                0            1        2
       5     RRR RRR    0.          0.          0.            0.          0.          0.                0            1        3
      92     RRR RRR    0.          0.          0.            0.          0.          0.                0            1        4
```

```
M A T E R I A L   P R O P E R T I E S

      HDR / URL   BLOWDOWN MODEL                                                                                            PAGE      6
                                                                                                                            24  MAR 81
MATERIAL      MATERIAL                                  WEIGHT           ELASTIC         POISSON'S       EXPANSION
 NUMBER   DESCRIPTION     TEMPERATURE                   DENSITY           MODULUS             RATIO    COEFFICIENT

      1          CPIPE     0.                         .1037E+06        .1987E+12        .2900E+00      0.
      2          SPIPE     0.                         .1123E+06        .1987E+12        .2900E+00      0.
      3          SPIPE     0.                         .1262E+06        .1987E+12        .2900E+00      0.
      4          CPIPE     0.                         .1091E+06        .1987E+12        .2900E+00      0.
      5          VALVE     0.                         .2118E+05        .1987E+12        .2900E+00      0.
      6          SPIPE     0.                         .9610E+05        .1987E+12        .2900E+00      0.
      7          SPIPE     0.                         .1199E+06        .9990E+12        .2900E+00      0.
```

```
P I P E   S E C T I O N   P R O P E R T I E S

      HDR / URL   BLOWDOWN MODEL                                                                                     PAGE      7
                                                                                                                     24  MAR 81
SCALE FACTOR  -  DIVIDE DIAMETER AND
WALL THICKNESS ENTRIES BY (FLU)             (    0.00000)          FLU    (CC 21-30)

SECTION          SHEAR        OUTSIDE           WALL   SHAPE FACTOR
 NUMBER        EFFECTS       DIAMETER      THICKNESS      FOR SHEAR     S E C T I O N   D E S C R I P T I O N

      1            YES         .41000         .02500        1.99440
      2            YES         .39860         .01930        1.99656
      3            YES         .40500         .01400        1.99829
      4            YES         .40600         .02500        1.99428
      5            YES         .40600         .01750        1.99730
      6            YES         .45500         .04180        1.98649
      7            YES        1.20000         .60000        1.33333
      8            YES         .50800         .04000        1.99933
```

```
P I P E   E L E M E N T S

      HDR / URL   BLOWDOWN MODEL                                                                                                     PAGE      3
                                                                                                                                     24  MAR 81

                                                                         A D D I T I O N A L   B E N D   D A T A
                           TUBE      END   - G E N E R A T I O N -    3RD PT     X3-ORD         Y3-ORD       Z3-ORD
PIPE NUMBER NODE NODE MATL SECT RELEASE  /1ST LEVEL/ /2ND LEVEL/     /SPEC      /BEND         /FACTOR      /TOLER-     TEMPE-   ELEMENT BAND-
   AND TYPE    1    2   ID   ID    CODES  NUMBER  INC NUMBER  INC      SYST     RADIUS         (P,K)          ANCE     RATURE    LENGTH WIDTH

        1B     6    8    1    1  0   0          0    1      1                   0.00           .54         0.00        0.0        .93    12
                                                                          7     .535**********(P)       .10000
                                           GLOBAL COORDINATES OF 3RD POINT = (  -1.97          17.30         -.52)
        2      8   10    2    2  0   0          0    1      0    1                                                     0.0        .52    12
        3B    10   11    1    2  0   0          0    1      1                   0.00          2.51         0.00        0.0        .66    12
                                                                          3    2.506*********(P)        .10000
                                           GLOBAL COORDINATES OF 3RD POINT = (    .00          17.30         -.00)
        4     12   14    2    2  0   0          0    1      0    1                                                     0.0        .63    12
        5B    14   16    1    1  0   0          0    1      1                   0.00          -.54         0.00        0.0        .54    12
                                                                          4     .535**********(P)       .10000
                                           GLOBAL COORDINATES OF 3RD POINT = (  -2.30          17.30         2.11)
        6     16   18    2    2  0   0          0    1      0    1                                                     0.0        .75    12
        7     18   20    2    2  0   0          0    1      0    1                                                     0.0        .75    12
        8B    20   22    1    1  0   0          0    1      1                   1.49           0.00         -.54        0.0        .76    12
                                                                          4     .535**********(P)       .10000
                                           GLOBAL COORDINATES OF 3RD POINT = (  -2.53          16.77         3.67)
        9     22   24    2    2  0   0          0    1      0    1                                                     0.0        .93    12
       10     24   26    2    3  0   0          0    1      0    1                                                     0.0        .93    12
       11     26   28    2    2  0   0          0    1      0    1                                                     0.0        .93    12
       12     28   30    2    2  0   0          0    1      0    1                                                     0.0        .93    12
       13     30   32    2    2  0   0          0    1      0    1                                                     0.0        .49    12
       14     32   34    2    2  0   0          0    1      0    1                                                     0.0        .34    12
       15     34   36    3    1  0   0          0    1      0    1                                                     0.0        .10    12
       16B    36   37    4    4  0   0          0    1      1                   4.66          -.61         0.00        0.0        .47    12
                                                                          5     .610**********(P)       .10000
                                           GLOBAL COORDINATES OF 3RD POINT = (  -3.37          12.11         3.83)
       17     38   40    3    5  0   0          0    1      0    1                                                     0.0        .56    12
       18     40   42    6    6  0   0          0    1      0    1                                                     0.0        .48    12
       19     42   43    5    7  0   0          0    1      0    1                                                     0.0        .57    12
       20     44   46    6    6  0   0          0    1      0    1                                                     0.0        .50    12
       21     46   48    3    5  0   0          0    1      0    1                                                     0.0        .20    12
       22B    48   49    4    4  0   0          0    1      1                   2.94          -.61         0.00        0.0        .32    12
                                                                          6     .610**********(P)       .10000
                                           GLOBAL COORDINATES OF 3RD POINT = (  -5.62          11.50         1.83)
       23     50   52    7    8  0   0          0    1      0    1                                                     0.0        .53    12
       24B    11   12    1    2  0   0          0    1      1                   0.00          2.51         0.00        0.0        .65    12
                                                                          3    2.506*********(P)        .10000
                                           GLOBAL COORDINATES OF 3RD POINT = (    .00          17.30         -.00)
       25B    37   38    4    4  0   0          0    1      1                   4.66          -.61         0.00        0.0        .47    12
                                                                          5     .610**********(P)       .10000
                                           GLOBAL COORDINATES OF 3RD POINT = (  -3.37          12.11         3.33)
       26     43   44    5    7  0   0          0    1      0    1                                                     0.0        .61    12
       27B    49   50    4    4  0   0          0    1      1                   2.94          -.61         0.00        0.0        .31    12
                                                                          5     .610**********(P)       .10000
                                           GLOBAL COORDINATES OF 3RD POINT = (  -5.62          11.50         1.83)
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE   1)

      HDR / URL   BLOWDOWN MODEL                                                                                      PAGE    10
                                                                                                                      24  MAR 81
LOAD CASE   1 --

  NODE  SPEC  SKEW REST-  CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST  NODE RAINT TRAINT   NODE       FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    49     6                            .10000E+01 0.          0.          0.          0.          0.                  0     1     1
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE   2)

      HDR / URL   BLOWDOWN MODEL                                                                                        PAGE    12
                                                                                                                        24  MAR 81
LOAD CASE   2 --

  NODE  SPEC  SKEW REST-  CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST  NODE RAINT TRAINT   NODE       FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    49     6                            0.          .10000E+01 0.         0.          0.          0.                  0      1     1
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE   3)

       HDR / URL   BLOWDOWN MODEL                                                                                   PAGE    14
                                                                                                                     24  MAR 81
LOAD CASE    3 --

  NODE  SPEC  SKEW REST-  CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST  NODE RAINT TRAINT   NODE       FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    43     6                           .10000E+01 0.          0.          0.          0.          0.                   0     1     1
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE   4)

      HDR / URL   BLOWDOWN MODEL
                                                                                                                                     PAGE    15
                                                                                                                                     24  MAR 81
LOAD CASE    4 --

  NODE  SPEC   SKEW REST-   CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST   NODE RAINT TRAINT   NODE       FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    37     5                              .10000E+01 0.          0.          0.          0.          0.                    0     1     1
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE   5)

      HDR / URL   BLOWDOWN MODEL                                                                                                      PAGE    13
                                                                                                                                      24  MAR 81
LOAD CASE   5 --

  NODE  SPEC  SKEW REST-  CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST  NODE RAINT TRAINT   NODE       FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    37     5                             0.          .10000E+01 0.          0.          0.          0.                   0     1     1
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE   6)

     HDR / URL   BLOWDOWN MODEL
                                                                                                                        PAGE  [illegible]
                                                                                                                        24  MAR 81
LOAD CASE   6 --

  NODE  SPEC  SKEW REST-  CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST  NODE RAINT TRAINT   NODE      FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    18     4                              .10000E+01 0.          0.          0.          0.          0.                0     1     1
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE   7)

      HDR / URL   BLOWDOWN MODEL                                                                                        PAGE    22
                                                                                                                        24  MAR 81

LOAD CASE   7 --

  NODE  SPEC  SKEW REST-  CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST  NODE RAINT TRAINT   NODE       FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    18     4                            0.          .10000E+01 0.          0.          0.          0.                0     1     1
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE   8)

      HDR / URL   BLOWDOWN MODEL                                                                                  PAGE   24
                                                                                                                  24  MAR 81

LOAD CASE   8 --

  NODE  SPEC  SKEW REST-  CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST  NODE RAINT TRAINT  NODE        FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    18    4                            0.          0.          .10000E+01 0.          0.          0.                  0     1     1
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE   9)

      HDR / URL   BLOWDOWN MODEL                                                                                  PAGE    25
                                                                                                                  24  MAR 81
LOAD CASE   9 --

  NODE  SPEC  SKEW REST-  CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST  NODE RAINT TRAINT   NODE       FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    11     2                            .10000E+01 0.          0.          0.          0.          0.                0     1     1
```

```
C O N C E N T R A T E D   F O R C E S   (LOAD CASE  10)

       HDR / URL   BLOWDOWN MODEL                                                                                    PAGE    23
                                                                                                                     24  MAR 81

LOAD CASE  10 --

  NODE  SPEC  SKEW REST-  CONS- REPEAT (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*) (X,R OR X*) (Y,S OR Y*) (Z,T OR Z*)  *GENERATION*
NUMBER  SYST  NODE RAINT TRAINT   NODE       FORCE       FORCE       FORCE      MOMENT      MOMENT      MOMENT  NUMBER   INC COUNT

    11     2                          0.          .10000E+01 0.          0.          0.          0.                      0     1     1
```

```
FLAG CONTROLLING THE METHOD USED TO
CREATE THE SYSTEM MASS MATRIX              =  (       1)            IELMS  (CC 16-20)
  EQ. 0, ELEMENT MASSES ARE NOT USED,
         ALL MASS DATA MUST BE INPUT IN
         THE  *MASSES*  DATA SECTION
  EQ. 1, ELEMENT MASSES ARE USED,  ANY DATA
         GIVEN IN THE  *MASSES*  DATA SECTION
         WILL AUGMENT THE ELEMENT-BASED MATRIX

ACCELERATION OF GRAVITY                    =  (        .98100E+01) FGEE   (CC 21-30)

FLAG FOR PRINTING THE SYSTEM MASS MATRIX   =  (       0)            IMPRT  (CC 31-35)
  EQ. 0, NO
  EQ. 1, YES
```

```
T I M E   H I S T O R Y   A N A L Y S I S   C O N T R O L   V A R I A B L E S

       HDR / URL   BLOWDOWN MODEL                                                                              PAGE    30
                                                                                                               24  MAR 81
NUMBER OF SOLUTION TIME STEPS                 =  (  5000)              IDT     (CC 16-20)

SOLUTION TIME STEP                            =  (       .20000E-03) FDT     (CC 21-30)

TIME AT THE START OF THIS SOLUTION            =  (      -.96600E-01) FTIMEO (CC 31-40)

METHOD TO BE USED FOR DIRECT INTEGRATION      =  (      N)             SN      (CC    41)
  EQ. N, NEWMARK*S METHOD
  EQ. W, WILSON THETA METHOD

VALUE OF ALPHA PARAMETER (NEWMARK)            =  (       .50000E+00) FA      (CC 42-50)

VALUE OF  BETA PARAMETER (NEWMARK)            =  (       .25000E+00) FB      (CC 51-60)

VALUE OF THETA PARAMETER (WILSON)             =  (      0.           ) FT      (CC 61-70)

ANALYSIS TYPE (TRANSIENT OR STEADY-STATE)     =  (      T)             ST      (CC    71)

PERIOD (STEADY-STATE ANALYSIS ONLY)           =  (      0.           ) FTL     (CC 72-80)

***  E R R O R  **  PRECEDING LINE.
SECTION (HISTORY ),  CARD(,   1),  COLUMNS (31-40).
ZERO (OR NEGATIVE) CONTROL PARAMETER.

PROCESSING TERMINATED FOR THIS SECTION.
```

```
D A M P I N G   R A T I O S

       HDR / URL   BLOWDOWN MODEL
                                                                                                                      PAGE     31
                                                                                                                      24  MAR 81

REFERENCE DAMPING RATIO FOR ALL MODES          =  (       0.          ) FDAMPO (CC 21-30)

MASS PROPORTIONAL       DAMPING CONSTANT       =  (        .12000E+01) FALPHA (CC 31-40)
(DIRECT INTEGRATION OPTION ONLY)

STIFFNESS PROPORTIONAL DAMPING CONSTANT        =  (        .63500E-04) FBETA  (CC 41-50)
(DIRECT INTEGRATION OPTION ONLY)
```

APPENDIX B

PRESSURE WAVE FLUID FORCES ON URL PIPE

APPENDIX B

PRESSURE WAVE FLUID FORCES ON URL PIPE

The approach used to determine the fluid forces on the URL pipe was to assume the value of the momentum terms in the linear momentum equation, from fluid mechanics (control volume formulation), to be small compared to the surface force terms. For this reason, the momentum terms, together with the body force term, were neglected for this analysis. The resulting equation to be solved for the fluid force on the pipe $\overline{F}_R$ is $\overline{F}_s = 0$. The solution is obtained simply as follows (see Figure B.1):

$$\overline{F}_s = -\overline{F}_R + p_1 A_1 \hat{i}_1 - p_2 A_2 \hat{i}_2 = 0 \qquad \text{(sum of the surface forces on the C.S.)}$$

$$\overline{F}_R = p_1 A_1 \hat{i}_1 - p_2 A_2 \hat{i}_2, \tag{B-1}$$

where $\overline{F}_R$ is the resultant force of a control volume on its corresponding section of pipe. This equation is applied, as follows, to the control volumes defined for this solution approach.

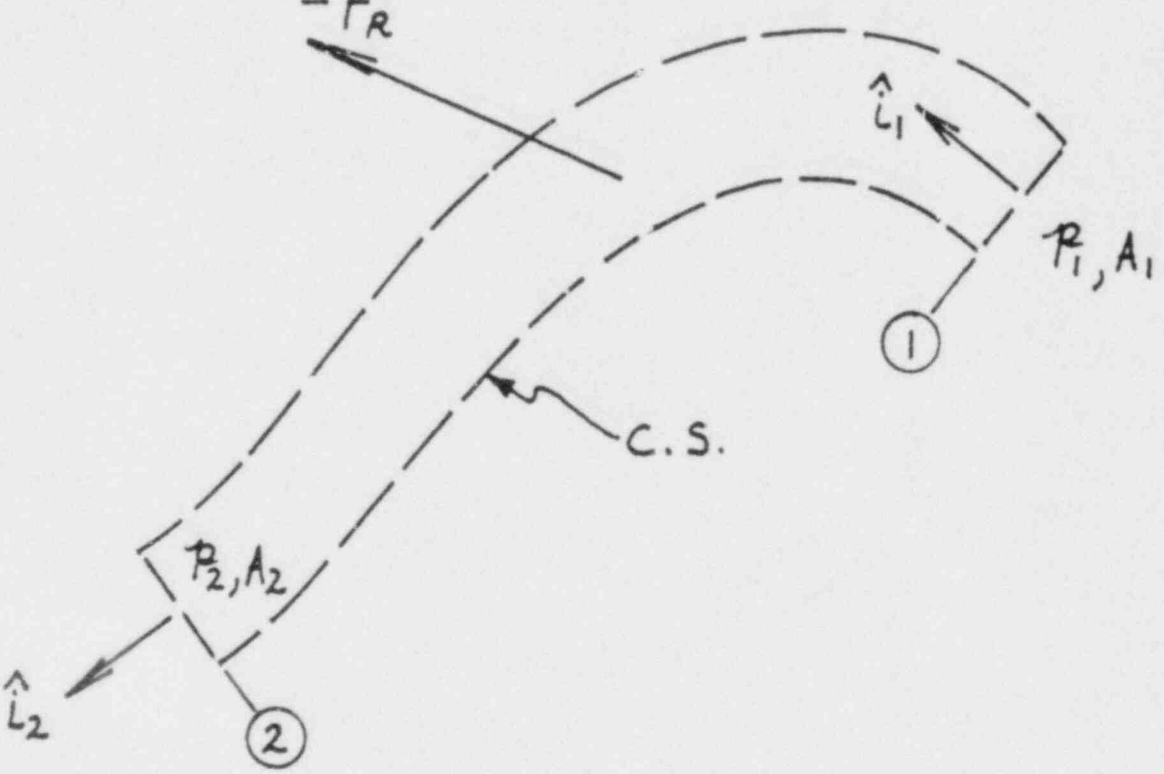


FIGURE B.1: Pipe Force on Control Volume.

SHEET 1 OF 4

ANCO

ANCO Engineers, Incorporated
1701 Colorado Avenue, Santa Monica, CA 90404
(213) 829-9721, 829-2624

MADE BY WBW DATE 7/21/81

CHECKED BY GEH DATE 9/11/81

DESCRIPTION G5P4a

CALCULATIONS FOR 1182-8 (NRC)

Force Of Fluid (Control Volumes) On Pipe

Apply equation B-1 as follows (use figures B.2-B.7):

$\angle P_1$:

$$\bar{F}_1 = P_1 A_1 \sin 29^\circ (-\hat{i}) + P_1 A_1 \cos 29^\circ \hat{j} + P_2 A_2 \hat{i}$$

$$= (P_2 A_2 - P_1 A_1 \sin 29^\circ)\hat{i} + P_1 A_1 \cos 29^\circ \hat{j}$$

$\angle P_2$:

$$\bar{F}_2 = -P_2 A_2 \hat{i} + P_3 A_3 \hat{i}$$

$$= (P_3 A_3 - P_2 A_2)\hat{i}$$

$\angle P_3$:

$$\bar{F}_3 = P_4 A_4 \hat{j} + P_5 A_5 \hat{i}$$

$$= P_5 A_5 \hat{i} + P_4 A_4 \hat{j}$$

$\angle P_4$:

$$\bar{F}_4 = P_6 A_6 \hat{k} + P_7 A_7 \cos 60^\circ \hat{i} + P_7 A_7 \sin 60^\circ \hat{j}$$

$$= P_7 A_7 \cos 60^\circ \hat{i} + P_7 A_7 \sin 60^\circ \hat{j} + P_6 A_6 \hat{k}$$

MADE BY	WBW	DATE	7/21/81
CHECKED BY	SBH	DATE	9/11/81

DESCRIPTION G5P4a

CALCULATIONS FOR 1182-B (NRC)

LP_5: $\bar{F}_5 = -P_7 A_7 \cos 15^\circ \hat{i} - P_7 A_7 \sin 15^\circ \hat{j}$

These equations were implemented in solving G5P4a. They were coded (programed) in the computer code PWFØRC. A listing of this code is given at the end of this appendix.

ANCO
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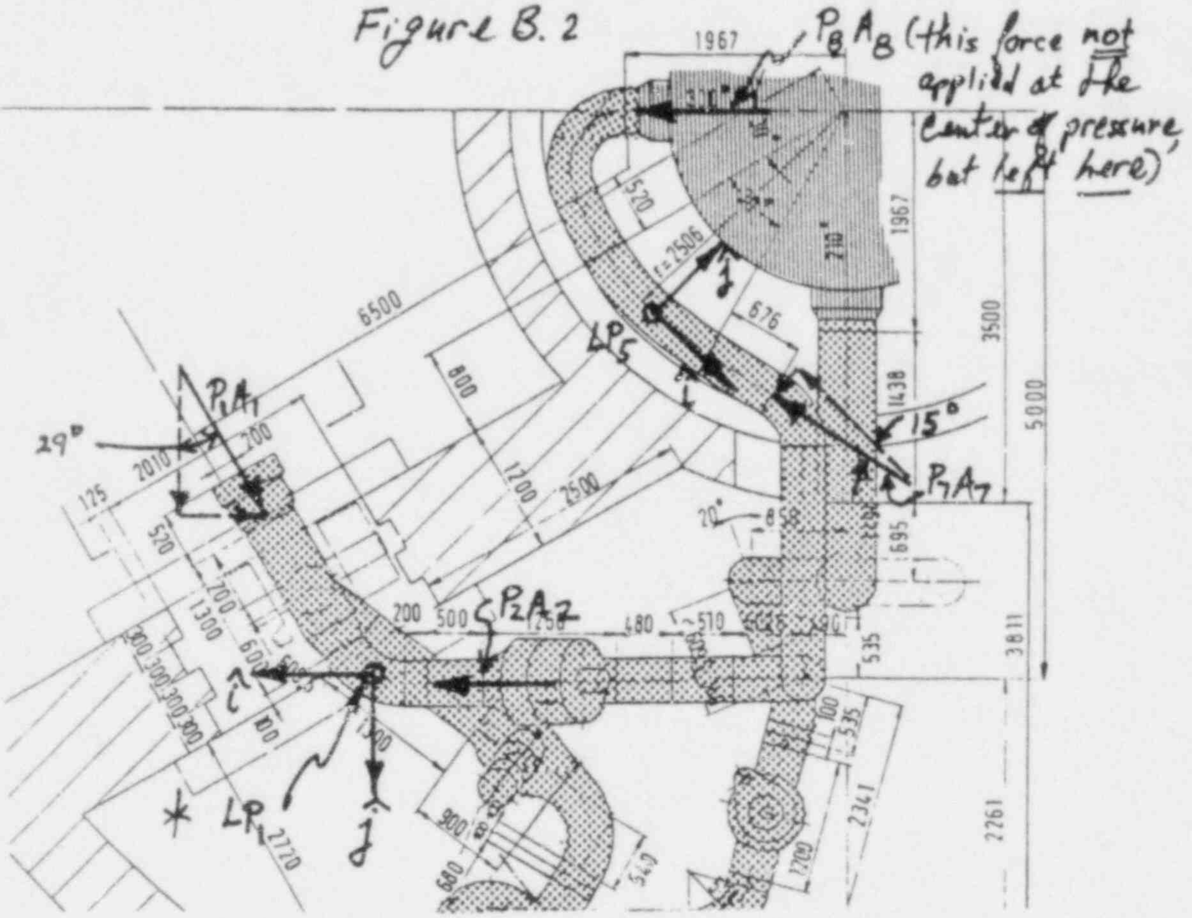
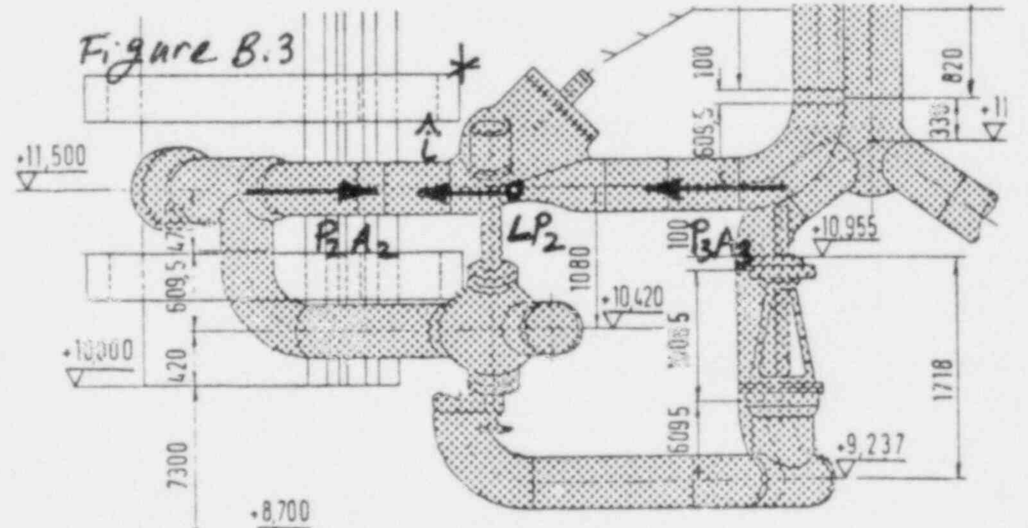
MADE BY WBW	DATE 7/21/81
CHECKED BY	DATE
DESCRIPTION G-SP4a	
CALCULATIONS FOR 1182-B (NRC)	

Figure B. 2



P_8A_8 (this force not applied at the center of pressure, but left here)

Figure B.3



* Note: See Figure B.7 concerning the definition of the unit vectors $\hat{i}$, $\hat{j}$, $\hat{k}$.

SHEET 4 OF 4

ANCO

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DESCRIPTION GSP4a

CALCULATIONS FOR 1182-8 (NRC)

Figure B.4

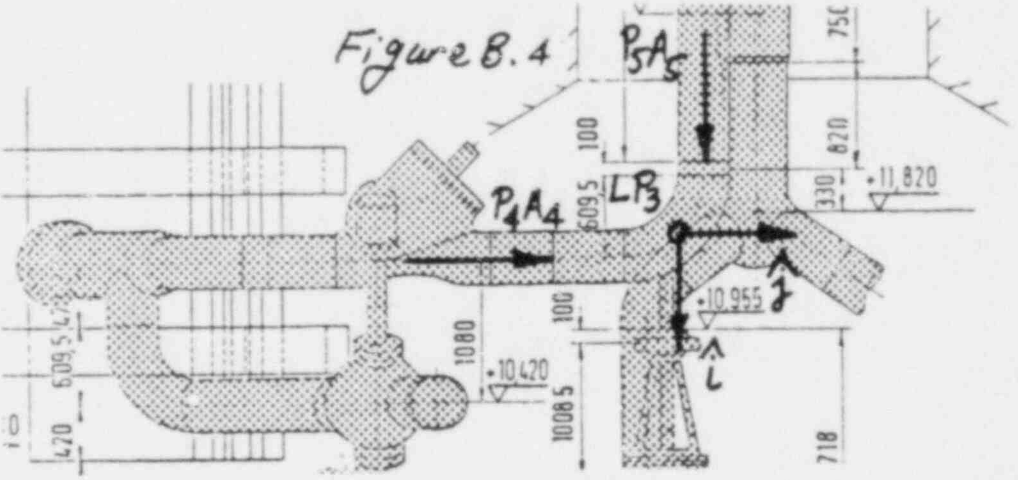


Figure B.5

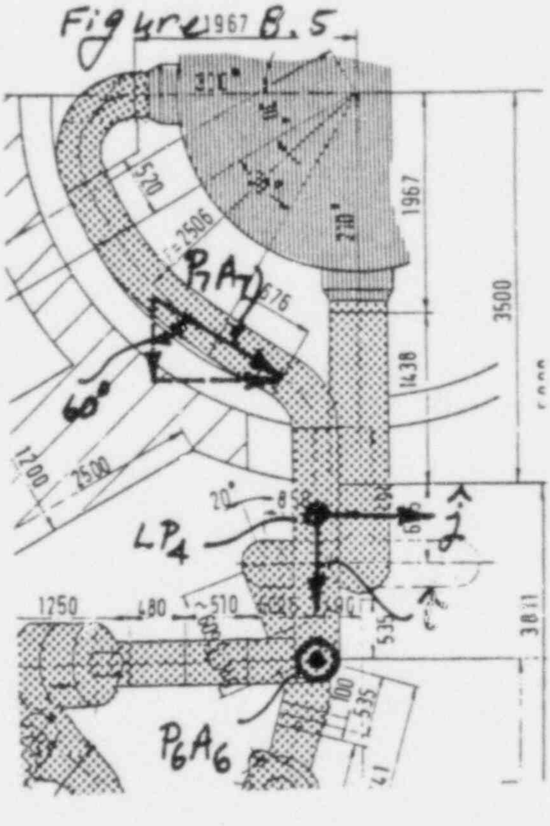


Figure B.6

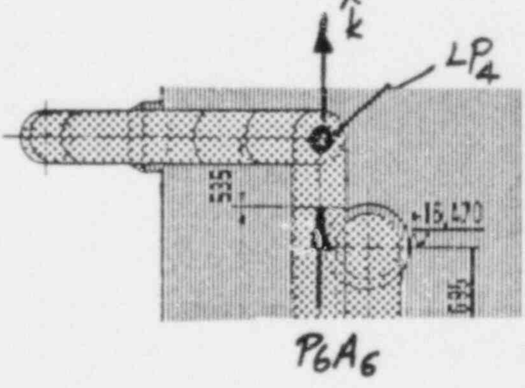
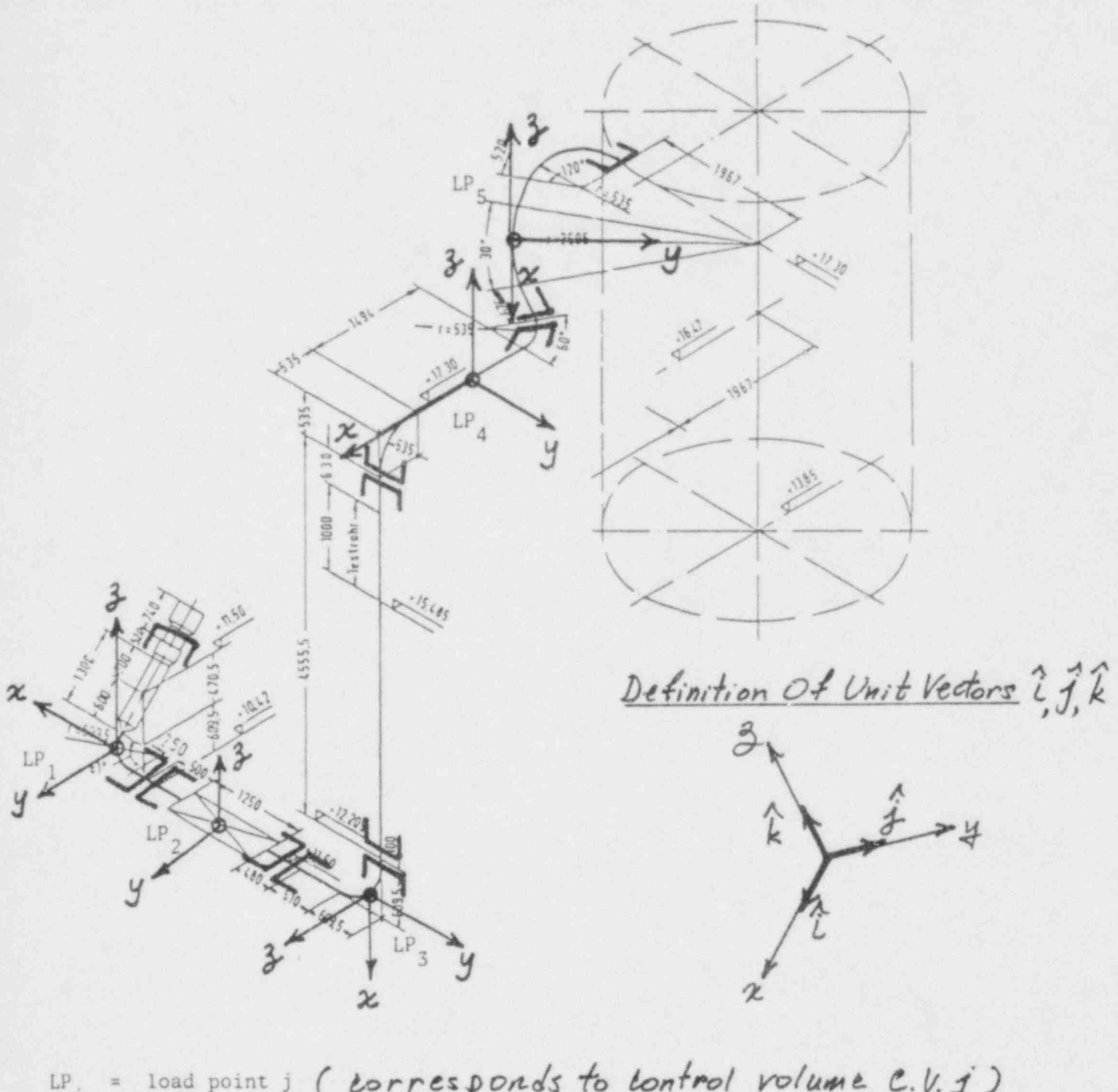


Figure B.7

LOCAL COORDINATE DIRECTIONS FOR APPLIED FLUID FORCES



Definition Of Unit Vectors $\hat{i}, \hat{j}, \hat{k}$

LP_j = load point j (corresponds to control volume C.V. j)

[ ] = bracket pair designates a control volume

```
      PROGRAM PWFORC(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,TAPE8)
C
C*****************************************************************************
C                          *** PWFORC ***
C           THIS  PROGRAM CALCULATES THE PRESSURE WAVE FORCES ON A PIPING
C           SYSTEM. THE PRESSURES ARE OBTAINED FROM EXPERIMENTAL PRESSURE
C           DATA . THIS PROGRAM APPLIES SPECIFICALLY TO THE JRL BLOWDOWN
C           LEG(HDR,WEST GERMANY). THE LEG IS FIXED AT THE REACTOR VESSE-
C           WALL AND AT THE TEE. IT IS A SINGLE RUN OF PIPE WITH NO
C           BRANCHES AND NO SUPPORTS(HANGERS,ETC.). THE FORCES(F) ARE
C           DETERMINED FOR FIVE(5) LOAD POINTS. TEN LOADS ARE DETERMINED.
C           THE PRESSURES ARE REPRESENTED BY THE ARRAY P.
C*****************************************************************************
C
      DIMENSION P(7,5000),A(7),F(10,5000),TITLE(40)
      DIMENSION TIME(5000),IWHERE(10),DT(5000)
      DIMENSION PO(7)
C
C
      REWIND 7
      REWIND 8
C
C     ** READ INPUT DATA **
C      * READ DATA FROM CARDS
      READ(5,10) TITLE
      READ(5,11) NTPTS
      READ(5,12) A
      READ(5,400) IWHERE
  400 FORMAT(10I5)
C      *CALL SUBROUTINE DOSYSR TO READ GERMAN DATA IN DOSYS FORMAT
      CALL DOSYSR(TIME,P,5000,7,IWHERE,NTPTS,8)
C     ** END OF READING DATA **
C
C      * BIAS THE PRESSURES
      DO 999 J=1,7
  999 PO(J) = P(J,1)
      DO 1000 IT=1,NTPTS
      DO 1000 J=1,7
 1000 P(J,IT) = P(J,IT) - PO(J)
C
C     ** CALC. AVERAGE TIME INCREMENT(ADT)**
      NM1 = NTPTS - 1
      DO 410 I=1,NM1
  410 DT(I) = TIME(I+1) - TIME(I)
      ADT = 0.0
      DO 420 I=1,NM1
  420 ADT = ADT + DT(I)
      ADT = ADT/NM1
C     ** COMPAIR DT(I) WITH ADT **
      DIFMAX = -1.0
      DO 430 I=1,NM1
      DIF = ABS(DT(I) - ADT)
      IF(DIF.GT.DIFMAX) DIFMAX = DIF
  430 CONTINUE
C
C     ** CALCULATE FORCES OF FLUID ON URL(BD) PIPE(PRESSURE WAVE ONLY)
C      *        FORCE INFORMATION
C          LOAD
C          POINT ANCO  FORCE   LP COORD.
C          (LP)  NODE  AT LP   DIRECTION
C           1     49   F(1,1)      X
C           1     49   F(2,1)      Y
C           2     43   F(3,1)      X
```

```
C             3      37   F(4,I)        X
C             3      37   F(5,I)        Y
C             4      18   F(6,I)        X
C             4      18   F(7,I)        Y
C             4      18   F(8,I)        Z
C             5      11   F(9,I)        X
C             5      11   F(10,I)       Y
C        * FORCES F(1,I) THRU F(10,I) ARE COMPONENTS IN LOCAL COORD. SYS.S
C
C        * PRESSURE INFORMATION
C          ANCO
C          NODE    PRESSURE  AREA(M**2)
C           51       P(1,I)    A(1) = 0.1083
C           46       P(2,I)    A(2) = 0.1083
C           43       P(3,I)    A(3) = 0.1083
C           40       P(4,I)    A(4) = 0.1083
C           36       P(5,I)    A(5) = 0.1018
C           22       P(6,I)    A(6) = 0.1018
C           14       P(7,I)    A(7) = 0.1018
C
C          (NOTE-- IN THE ABOVE - I - IS INTEGER TIME.)
C          (NOTE--ANCO NODES(NO.S) ARE THOSE FROM THE EASE2 MODEL FEB81)
C         * THE AREA A IN THE EQ.S FOR  F  IS ACTUALLY  A*  = 10**5*A(M**2)
C          AND HAS UNITS N/BAR.
C         * THE UNITS OF  P  ARE BAR.
C         * THE UNITS OF  F  ARE N.
C
C         * INITIALIZE ARRAY F
        NTPTSS = (INT((NTPYS-0.5)/8)+1)*8
        DO 300 K=1,10
        DO 300 I=1,NTPTSS
  300   F(K,I) = 1.0
C
C
C         * CALC. ARRAY F
        DO 100 IT=1,NTPTS
        F(1,IT) = P(2,IT)*A(2) - 0.485*P(1,IT)*A(1)
        F(2,IT) = 0.875*P(1,IT)*A(1)
        F(3,IT) = P(3,IT)*A(3) - P(2,IT)*A(2)
        F(4,IT) = P(5,IT)*A(5)
        F(5,IT) = P(4,IT)*A(4)
        F(6,IT) = 0.500*P(7,IT)*A(7)
        F(7,IT) = 0.866*P(7,IT)*A(7)
        F(8,IT) = P(6,IT)*A(6)
        F(9,IT) = -0.966*P(7,IT)*A(7)
        F(10,IT) = -0.259*P(7,IT)*A(7)
  100   CONTINUE
C
C       ** END CALCULATING FORCES **
C
C       ** WRITE OUT DATA **
C       * WRITE THE FORCES OUT TO TAPE7(EASE2 FORMAT)
        LTAPE = 7
        DO 150 K=1,10
        WRITE(LTAPE,207) (F(K,I),I=1,NTPTSS)
        ENDFILE LTAPE
  150   CONTINUE
C
C       * WRITE OUT TO OUTPUT
        WRITE(6,200)
        WRITE(6,201) TITLE
        WRITE(6,202) NTPTS
        WRITE(6,440) TIME(1),ADF,DIFMAX
```

```
 440  FORMAT( 1X,16HADDITIONAL INFO.,//,1X,
    *             8HTIMEO = ,E12.4,/,1X,
    *            10HAVG. DT = ,E12.4,/,1X,
    *            13HMAX.VAR.DT = ,E12.4,//)
      WRITE(6,203) A
      WRITE(6,217) IWHERE
 217  FORMAT(1X,15HIWHERE ARRAY = ,10I5)
      WRITE(6,998) PO
 998  FORMAT(//,1X,23HBIASING PRESSURES PO = ,7E12.3)
      DO 210 K=1,7
      WRITE(6,204) K
      WRITE(6,205) (P(K,I),I=21,NTPTS,20)
 210  CONTINUE
      DO 211 K=1,10
      WRITE(6,206) K
      WRITE(6,205) (F(K,I),I=21,NTPTS,20)
 211  CONTINUE
C
C     ** END OF WRITING OUT **
C
C     ** FORMATS **
C
  10  FORMAT(40A2)
  11  FORMAT(10I5)
  12  FORMAT(8F10.4)
 200  FORMAT(1H1,47HPROGRAM PWFORC -- CALCULATES THE PRESSURE WAVE ,
    *            17HFORCE ON URL PIPE,//)
 201  FORMAT(1H ,40A2,//)
 202  FORMAT(1H ,23HNTPTS(NO. TIME PT.S) = ,I5,//)
 203  FORMAT(1H ,27HFLOW AREAS(A1,A2,...,A7) = ,7E12.3,//)
 204  FORMAT(1H1,24HPRESSURE TIME HISTORY P(,I1,1H),//)
 205  FORMAT(1X ,10E12.3)
 206  FORMAT(1H1,21HFORCE TIME HISTORY F(,I2,1H))
 207  FORMAT(8E10.4)
C     ** END FORMATS **
      STOP
      END
```

```
C***********************************************************************DOSY1000
C                                                                       DOSY1010
      SUBROUTINE DOSYSR(TIME,PRESSR,MAXPT,NPSR,IWHERE,NPTS,ICHAN)       DOSY1020
C                                                                       DOSY1030
C***********************************************************************DOSY1040
C                                                                       DOSY1050
C     PURPOSE THIS ROUTINE READS A FILE THAT IS IN A DOSYS FORMAT,      DOSY1060
C             PRINTS THE HEADER INFORMATION, AND RETURNS THE TIME       DOSY1070
C             HISTORY DATA INDICATED BY IWHERE. NOTE THAT THIS          DOSY1080
C             PROGRAM IS DESIGNED TO READ THE DATA FROM A MASS STORAGE  DOSY1090
C             FILE BUT MAY ALSO WORK DIRECTLY FROM TAPE.                DOSY1100
C                                                                       DOSY1110
C     INPUTS  MAXPT   THIS IS THE MAXIMUM NUMBER OF POINTS IN THE       DOSY1120
C                     TIME HISTORY. THIS IS USED FOR DIMENSIONNING      DOSY1130
C                     OF TIME AND PRESSR.                               DOSY1140
C             NPSR    THIS IS THE NUMBER OF PRESSURES TO BE READ.       DOSY1150
C             IWHERE  ARRAY OF TRANSDUCER NUMBER GIVING LOCATION IN     DOSY1160
C                     DOSYS TAPE OF THE CORRESPONDING PRESSURE,         DOSY1170
C                     (I.E. IF IWHERE(2)=7 THEN TRANSDOUCER 7 IS        DOSY1180
C                     STORED AT PRESSR(2)).                             DOSY1190
C             ICHAN   CHANNEL OF DOSYS INPUT TAPE                       DOSY1200
C                                                                       DOSY1210
C     OUTPUTS TIME    SINGLE DIMENSION ARRAY OF TIME AT EACH POINT      DOSY1220
C             PRESSR  TWO DIMENSIONAL ARRAY OF PRESSURES(NPSR,NPTS)     DOSY1230
C             NPTS    ACTUAL NUMBER OF POINTS IN DOSYS INPUT TAPE       DOSY1240
C                                                                       DOSY1250
C***********************************************************************DOSY1260
C                                                                       DOSY1270
C     MOD       DATE    BY        REASON                                DOSY1280
C     1.00      FEB 81  LJS       ORIGINAL                              DOSY1290
C                                                                       DOSY1300
C***********************************************************************DOSY1310
      DIMENSION TIME(MAXPT),PRESSR(NPSR,MAXPT),IWHERE(NPSR),DINPUT(256)DOSY1320
      DIMENSION TSTRUN(2),DESCRP(3),TLABEL(2),ICOORD(3),TSTAT(3)        DOSY1330
C                                                                       DOSY1340
C     READ DOSYS HEADER INFORMATION AND OUTPUT TO PRINTER(CHAN 6)       DOSY1350
C                                                                       DOSY1360
      READ(ICHAN,9001) USERID                                           DOSY1370
      WRITE(6    ,9101) USERID                                          DOSY1380
      READ(ICHAN,9002) HDR                                              DOSY1390
      WRITE(6    ,9102) HDR                                             DOSY1400
      READ(ICHAN,9003) TSTRUN                                           DOSY1410
      WRITE(6    ,9103) TSTRUN                                          DOSY1420
      READ(ICHAN,9004) TSTTYP,ICODE,MODEL,ITYPE,IDAMP                   DOSY1430
      WRITE(6    ,9104) TSTTYP,ICODE,MODEL,ITYPE,IDAMP                  DOSY1440
      READ(ICHAN,9001) IDATE                                            DOSY1450
      WRITE(6    ,9101) IDATE                                           DOSY1460
      READ(ICHAN,9006) DESCRP                                           DOSY1470
      WRITE(6    ,9106) DESCRP                                          DOSY1480
      DO 100 I=7,16                                                     DOSY1490
        READ(ICHAN,9007)                                                DOSY1500
  100 CONTINUE                                                          DOSY1510
C                                                                       DOSY1520
C     READ TRANSDUCER IDENTIFICATION HEADER AND OUTPUT TO PRINTER       DOSY1530
C                                                                       DOSY1540
      READ(ICHAN,9017) NTRAN                                            DOSY1550
      WRITE(6    ,9107) NTRAN
      READ(ICHAN,9017) NSAMP                                            DOSY1570
      WRITE(6    ,9107) NSAMP
      IF(NSAMP.GT.MAXPT) GOTO 1000                                      DOSY1590
      DO 200 I=1,NTRAN                                                  DOSY1600
        READ(ICHAN,9019) TNAME,TCODE,TPUC,TDIR,TLABEL,TSYS,ICOORD,JCODEDOSY1610
        WRITE(6    ,9119) TNAME,TCODE,TPUC,TDIR,TLABEL,TSYS,ICOORD,JCODEDOSY1620
```

```
         READ(ICHAN,9020) TSTAT                                      DDSY1630
         WRITE(6   ,9120) TSTAT                                      DDSY1640
  200 CONTINUE                                                       DDSY1650
C                                                                    DDSY1660
C     READ INPUT DATA AND SAVE REQUESTED PRESSURES                   DDSY1670
C     DONT READ PRESSURES IF IWHERE(1)=0.                            DDSY1680
C                                                                    DDSY1690
      IF(IWHERE(1).EQ.0) GOTO 500                                    DDSY1700
      DO 400 I=1,NSAMP                                               DDSY1710
        READ(ICHAN,9021) TIME(I),(DINPUT(J),J=1,NTRAN)               DDSY1720
        DO 300 J=1,NPSR                                              DDSY1730
          PRESSR(J,I) = DINPUT(IWHERE(J))                            DDSY1740
  300   CONTINUE                                                     DDSY1750
  400 CONTINUE                                                       DDSY1760
  500 CONTINUE                                                       DDSY1770
      NPTS = NSAMP                                                   DDSY1780
      RETURN                                                         DDSY1790
 1000 CONTINUE
      WRITE(6,9000)
      STOP
C                                                                    DDSY1800
C     FORMATS                                                        DDSY1810
C                                                                    DDSY1820
 9000 FORMAT(1X,31H UNABLE TO HANDLE NO. OF POINTS)
 9001 FORMAT(I6,74X)                                                 DDSY1830
 9002 FORMAT(A6,74X)                                                 DDSY1840
 9003 FORMAT(A10,A2,68X)                                             DDSY1850
 9004 FORMAT(A1,A3,2I1,I2,I6,66X)                                    DDSY1860
 9006 FORMAT(2A10,A4,56X)                                            DDSY1870
 9007 FORMAT(80X)                                                    DDSY1880
 9017 FORMAT(I5,75X)                                                 DDSY1890
 9019 FORMAT(A6,A2,A6,A1,A10,A4,A3,3I5,A1,32X)                       DDSY1900
 9020 FORMAT(2A10,A8,52X)                                            DDSY1910
 9021 FORMAT(6E12.5,8X)                                              DDSY1920
 9101 FORMAT(1X,I6)                                                  DDSY1930
 9102 FORMAT(1X,A6)                                                  DDSY1940
 9103 FORMAT(1X,A10,A2)                                              DDSY1950
 9104 FORMAT(1X,A1,A3,2I1,I2,I6)                                     DDSY1960
 9106 FORMAT(1X,2A10,A4)                                             DDSY1970
 9107 FORMAT(1X,I5)                                                  DDSY1980
 9119 FORMAT(1X,A6,A2,A6,A1,A10,A4,A3,3I5,A1)                        DDSY1990
 9120 FORMAT(1X,2A10,A8)                                             DDSY2000
      END                                                            DDSY2010
```

APPENDIX C

PROCESSING OF OUTPUT FROM EASE2 AND COMPUTATION OF ADDITIONAL STRESSES

APPENDIX C

PROCESSING OF OUTPUT FROM EASE2 AND COMPUTATION OF ADDITIONAL STRESSES

The computer code PWSTRS was written to apply coordinate transformations to the displacement and acceleration output from EASE2, compute additional stress components, change to desired units (i.e., displacements were to have units of mm), and format solution results in DOSYS format. A listing of this code is given in this appendix.

```
      PROGRAM   PWSTRS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,
     *               TAPE8,TAPE9,
     * TAPE10,TAPE11,TAPE12,TAPE13,TAPE14,TAPE15,TAPE16,TAPE17,TAPE18,
     * TAPE19,TAPE20,TAPE21,TAPE22,TAPE23,TAPE24,TAPE25,TAPE26,TAPE27,
     * TAPE28,TAPE29,TAPE30,TAPE31)
C***********************************************************************
C
C                      *** PWSTRESS ***
C
C     THIS PROGRAM READS TAPE1(EASE2 TIME HISTORY OUTPUT),READS THE
C     PRESSURE DATA(DOSYS FORMAT),CALCULATES SOME STRESS DATA, AND
C     OUTPUTS EASE2 RESPONSE DATA(DOSYS FORMAT)
C
C***********************************************************************
C
      DIMENSION HED1(8),HED2(8)
      DIMENSION NORS(7),S1(2,8),S2(2,8),S3(8),L3RN(8),XI(9)
      DIMENSION TTIME(   1),DX(3,   1),DY(3,   1),DZ(3,   1)
      DIMENSION AX(1,   1),AY(1,   1),AZ(1,   1)
      DIMENSION STPB(5,   1),STEN(5,   1),SBEN(5,   1),STOR(5,   1)
      DIMENSION MY(5,   1),MZ(5,   1),ALPHA(5,   1)
      DIMENSION FX(5,   1),FY(5,   1),FZ(5,   1),P(7,5000)
      DIMENSION SPA(5,   1),SPT(5,   1),SA(5,   1),SV(5,   1)
      DIMENSION R2M1(5),IWHERE(10)
      DIMENSION TD(3,3,3),TA(3,3),TF(3,3,5)
      DIMENSION PRTIME(5000)
      DIMENSION XOUT(   1,42)
      DIMENSION  IWH(42)
C
      REAL MY,MZ
      INTEGER E2HIST
      INTEGER TTAPE,DTAPE,ATAPE,STAPE,ALTAPE,FTAPE
C
      DATA    E2HIST/1/
      DATA    LTAPE8,LTAPE9/8,9/
      DATA TTAPE,TAPOUT/10,9/
      DATA R2M1/0.0, 0.1974    ,0.0, 0.1974    , 0.2259     /
C      * TD,TA, AND TF ARE THE COORD. TRANS. MATRICIES FOR THE DISPL., ACCEL.,
C        AND FORCE , RESPECTIVELY.
      DATA TD/0.5,0.866,0.0,0.0,0.0,1.0,0.866,-0.5,0.0,               (IND=1)
     *        0.0,0.866,-0.5,-1.0,0.0,0.0,0.0,0.5,0.866,              (IND=2)
     *       -0.866,-0.5,0.0,0.0,0.0,1.0,-0.5,0.866,0.0/              (IND=3)
     DATA TA/-0.866,-0.5,0.0,0.0,0.0,1.0,-0.5,0.866,0.0/              (IND=1)
      DATA TF/0.259,0.966,0.0,0.0,0.0,1.0,0.966,-0.259,0.0,           (IND=1)
     *        -0.5,0.866,0.0,0.0,0.0,1.0,0.866,0.5,0.0,               (IND=2)
     *        0.0,0.866,-0.5,-1.0,0.0,0.0,0.0,0.5,0.866,              (IND=3)
     *       -0.866,-0.5,0.0,0.0,0.0,1.0,-0.5,0.866,0.0,              (IND=4)
     *       -0.866,-0.5,0.0,0.0,0.0,1.0,-0.5,0.866,0.0/              (IND=5)
      DATA  MA,M8,M1,M2/20,20,20,20/
      DATA IWHERE/20,15,13,13,7,5,4/
C
      REWIND E2HIST
      REWIND LTAPE8
      REWIND LTAPE9
      DO 666 I=10,29
  666 REWIND I
      ISKIP=0
C
C     ** READ PRESSURE TIME HISTORIES
C     * CALL SUBROUTINE DOSYSR TO READ GERMAN DATA IN DOSYS FORMAT
      CALL DOSYSR(PRTIME,P,5000,7,IWHERE,NTPTS,8)
C
C     C O N T R O L   R E C O R D
```

```
C
C       VARIABLES
C
C       HED1,HED2     = EASE2 TITLE CARDS(EACH 8A10)
C       IDT           = NUMBER OF SOLUTION STEPS
C       FDT           = TIME STEP (INCREMENT)
C       NORS          = NUMBER OF OUTPUT REQUEST SETS IN EACH OF THE
C                       SEVEN CATAGORIES (NODE,FORC,BEAM,MEMB,SHEL,
C                       SOLI,PIPE) AS DETERMINED BY THE DATA ENTRIES
C                       GIVEN FOR FOR OUTPUT REQUESTS
        READ(E2HIST) HED1,HED2,IDT,FDT,FTIMEO,NORS
C       ** WRITE(PRINT) HEADING AND PERTINENT INFO.
        WRITE(6,300)
  300  FORMAT(1H1,46HPWSTRESS - FROM EASE2 AND PRESS DATA IT CALC.S,
     *              37H             AND OUTPUTS RESPONSE INFO.,///)
        WRITE(6,301) HED1,HED2,IDT,FDT,FTIMEO,NORS
  301 FORMAT(1X,7HTITLE- ,8A10,/,8X,8A10,//,1X,19HNUMBER OF SOLUTION,
     *              8HSTEPS = ,I5,//,1X,23HTIME STEP(INCREMENT) = ,E10.3,
     *          //,1X,25HTIME AT SOLUTION START = ,E10.3,//,1X,
     *             37HNO. OUTPUT SETS IN EACH OF 7 CAT.S = ,7I6,////)
C
        IF(EOF(E2HIST))1000,5
C
C       H E A D E R   R E C O R D
C
C       VARIABLES
C
C       KEY           = CATEGORY (1=NODE,2=FORC,3=BEAM,...7=PIPE)
C       NOS           = AN OUTPUT SET NUMBER IN THE KEY-TH CATEGORY
C                       (1.LE.NOS.LE.NORS(KEY))
C       ITPH          = SOLUTION TIME STEP INTERVAL AT WHICH OUTPUT
C                       IS WRITTEN TO THE E2HIST FILE
C       MAXCOL          MAXIMUM NUMBER OF REQUEST QUANTITIES IN THE
C                       NOS-TH OUTPUT SET,KEY-TH CATEGORY
C                        (1.LE.MAXCOL.LE.8)
C
C       S1(1,J),S1(2,J)= 1 CHARACTER(A3,A10),LINE 1 OUTPUT HEADING
C                          FOR THE J-TH REQUEST QUANTITY (E.G.,34K-T,
C                       TRANSLATION)
C       S2(1,J),S2(2,J)= 1 CHARACTER(A3,A10), LINE 2 OUTPUT HEADING
C                       FOR THE J-TH REQUEST QUANTITY (E.G.,34 AC,
C                       ACCELERATION)
C
C               S3( J)= 9 CHARATER (A9). LINE 3 OUTPUT PREFIX
C                       FOR ALL *MAXCOL*REQUEST QUANTITIES. NOTE
C                       THAT FOR THE CASE (S3(J).EQ.9H       ACS),
C                       TH=J-TH REQUEST QUANTITY IS AN ARITHMETIC
C                       COMPUTATION SEQUENCE (NUMBER*L3RN(J)*),AND
C                       S1(1,J),S1(2,J) AND S2(1,J),S2(2,J) ARE THE
C                       ACS LINE 1 AND LINE 2 HEADINGS. IF THE
C                       J-TH REQUEST IS NOT AN ACS QUANTITY, S3(J)
C                       DEPENDS ON THE CATEGORY NUMBER (KEY) AS GIVEN
C                       IN THE FOLLOWING TABLE
C
C                       CATEGORY NUMBER OUTPUT PREFIX, S3(J)
C                                  1,2 9H    NODE ,
C                                    3 9H    BEAM
C                                    4 9H    MEMBRANE ,
C                                    5 9H    SHELL ,
C                                    6 9H    SOLID ,
C                                    7 9H    PIPE ,
C
C       L3RN(J)       = LINE 3 REFERENCE NUMBER FOR THE J-TH REQUEST
```

```
C                    QUANTITY
C                    KEY  .EQ.1,2         . NODE NUMBER
C                    KEY  .EQ.3,4,5,6,7   . ELEMENT NUMBER
C                    S3(J).EQ.9H       ACS. ACS NUMBER
C
    5  READ(E2HIST)KEY,NOS,ITPH,MAXCOL,
     *             (S1(1,J),S1(2,J),J=1,MAXCOL),
     *             (S2(1,J),S2(2,J),J=1,MAXCOL),
     *             (S3(  J),L3RN(J),J=1,MAXCOL)
       IF(EOF(E2HIST))1060,80
   80  CONTINUE
       WRITE(6,302) KEY,NOS,ITPH
  302  FORMAT(1X,24HINFO. FROM HEADER RECORD,//,
     *        9X,20HCATEGORY NO.(KEY) = ,I5,/ ,
     *        9X,32HOUTPUT SET NO. IN KEY-TH CAT. = ,I5,/,
     *        9X,18HOUTPUT INTERVAL = ,I5,/)
       WRITE(6,303) S3(1),L3RN(1)
  303  FORMAT(9X,A9,I5,//)
       L = L3RN(1)
C      ** BRANCHING,DEPENDENT UPON TYPE OF DATA
       IF(KEY.EQ.1) GOTO 51
       IF(KEY.EQ.2) GOTJ 53
       IF(KEY.EQ.7) GOTO 52
C      ** READ AND SET UP NODE DATA FOR OUTPUT(DISPL.S AND ACCEL.S)
   51  CONTINUE
       IF(L.EQ.[illegible]4)IND=1
       IF(L.EQ.[illegible])IND=2
       IF(L.EQ.42)IND=1
       IF(L.EQ.43)IND=3
C      (IND REFERRS TO THE INTERNAL NODE NUMBERS FOR OUTPUT OF NODE
C      DATA(KEY=1).)
       WRITE(6,304) L,IND
  304  FORMAT(1X,32HINFO. FROM COMP. SEQ.(NODE DATA),//,
     *        9X,20HEXTERNAL NODE NO. = ,I5,/,
     *        9X,20HINTERNAL NODE NO. = ,I5,//)
       GOTO 10
C      ** READ AND SET UP PIPE DATA FOR OUTPUT(STRESSES)
   52  CONTINUE
       IF(L.EQ.1)IND=1
       IF(L.EQ.7)IND=2
       IF(L.EQ.15)IND=3
       IF(L.EQ.17)IND=4
       IF(L.EQ.21)IND=5
C      (IND REFERRS TO THE INTERNAL NODE NUMBERS FOR OUTPUT OF PIPE
C      DATA(KEY=7).)
       WRITE(6,305) L,IND
  305  FORMAT(1X,32HINFO. FROM COMP. SEQ.(PIPE DATA),//,
     *        9X,20HEXTERNAL PIPE NO. = ,I5,/,
     *        9X,20HINTERNAL NODE NO. = ,I5,//)
       GOTO 10
C      ** READ AND SET UP FORCE DATA FOR OUTPUT (FORCES)
   53  CONTINUE
       IF(L.EQ.11)IND=1
       IF(L.EQ.18)IND=2
       IF(L.EQ.37)IND=3
       IF(L.EQ.43)IND=4
       IF(L.EQ.49)IND=5
C      (IND REFERRS TO THE INTERNAL NODE NUMBERS FOR OUTPUT OF FORCE
C      DATA(KEY=2).)
       WRITE(6,306) L,IND
  306  FORMAT(1X,33HINFO. FROM COMP. SEQ.(FORCE DATA).//
     *        9X,20HEXTERNAL NODE NO. = ,I5,/,
     *        9X,20HINTERNAL NODE NO. = ,I5,//)
```

```
C
C      DEFINITION OF INTERNAL NODE NUMBERS(IND)         (2/13/81)
C
C      IND REFERRS TO A NUMBERING SYSTEM WITHIN THIS CODE THAT
C      CORRESPONDS TO AN EXTERNAL(PHYSICAL) NUMBERING SYSTEM OF
C      NODE AND ELEMENT NUMBERS.
C
C           EXTERNAL*                NODE DATA
C           NODE                     CORRESPONDING
C           NUMBER        IND        RESPONSE QUANT.
C            14            1         DISPL(3.4M VOM RDB-STUTZEN)
C            22            2         DISPL(7.7M VOM RDB-STUTZEN)
C            42            1         ACCEL(AM VENTIL)
C            43            3         DISPL(AM VENTIL)
C
C           EXTERNAL*                ELEMENT DATA
C           ELEMENT                  CORRESPONDING
C           NUMBER        IND        RESPONSE QUANT.
C            1             1         STRESS(MESSEBENE A)
C            7             2         STRESS(MESSEBENE C1)
C            15            3         STRESS(MESSEBENE M1)
C            17            4         STRESS(MESSEBENE E)
C            21            5         STRESS(MESSEBENE F)
C
C           EXTERNAL*                FORCE DATA
C           NODE                     CORRESPONDING
C           NUMBER        IND        RESPONSE QUANT.
C            11            1         FORCE
C            18            2         FORCE
C            37            3         FORCE
C            43            4         FORCE
C            49            5         FORCE
C
C      * NOTE- THESE ARE THE EASE2 NODE AND ELEMENT NUMBERS(FEB 81)
C
C      E2HIST D A T A
C
C      VARIABLES
C
C      TIME          = TIME AT WHICH HISTORY RESULTS ARE SAVED ON THE
C                      E2HIST FILE
C      XI(J)         = VALUE OF THE J-TH REQUEST QUANTITY AT SOLUTION
C                      TIME = TIME-.
C
C       * SET I = 1 (INTEGER TIME = 1). THIS IS FOR LOOP FROM STATMENT 10 TO 20.
   10  I = 1
C
       DO 20 ILOOP=1,IDT
       IF(MOD(I,ITPH).NE.0) GOTO 20
       READ(E2HIST) TIME,(XI(J),J=1,MAXCOL)
       IF(ISKIP.EQ.1) GOTO 60
C      ** GENERATE ARRAY OF SOLUTION TIMES
       TTIME(I) = TIME
       WRITE(TTAPE) TTIME(I)
   60  CONTINUE
C      ** BRANCHING DEPENDENT UPON TYPE OF DATA
       IF(KEY.EQ.1) GOTO 55
       IF(KEY.EQ.2) GOTO 57
       IF(KEY.EQ.7) GOTO 56
C      ** NODE DATA FOR OUTPUT
   55  CONTINUE
       IF(L.EQ.42) GOTO 70
C      * DISPLACEMENT DATA( IN THE FOLLOWING  D = TD*XI , WHERE D ARE THE LOCAL
```

```
C          DISPLACEMENTS, TD IS THE TRANSFORMATION MATRIX, AND XI ARE THE GLOBAL
C          DISPLACEMENTS.)
        DX(IND,I) = (TD(1,1,IND)*XI(1)  +  TD(1,2,IND)*XI(2)  +
      * TD(1,3,IND)*XI(3))*1000.0
        DY(IND,I) = (TD(2,1,IND)*XI(1)  +  TD(2,2,IND)*XI(2)  +
      * TD(2,3,IND)*XI(3))*1000.0
        DZ(IND,I) = (TD(3,1,IND)*XI(1)  +  TD(3,2,IND)*XI(2)  +
      * TD(3,3,IND)*XI(3))*1000.0
C         (DISPLACEMENT AT IND IS (DX,DY,DZ), UNITS ARE MM.)
        DTAPE = 10 + IND
        WRITE(DTAPE) DX(IND,1),DY(IND,1),DZ(IND,1)
        GOTO 20
   70   CONTINUE
C         * ACCELERATION DATA( A = TA*XI )
        AX(IND,I) = (TA(1,1)*XI(1)  +  TA(1,2)*XI(2)  +
      * TA(1,3)*XI(3))/9.81
        AY(IND,I) = (TA(2,1)*XI(1)  +  TA(2,2)*XI(2)  +
      * TA(2,3)*XI(3))/9.81
        AZ(IND,I) = (TA(3,1)*XI(1)  +  TA(3,2)*XI(2)  +
      * TA(3,3)*XI(3))/9.81
C         (ACCELERATION AT IND IS(AX,AY,AZ), UNITS ARE G-S.)
        ATAPE = 13 + IND
        WRITE(ATAPE) AX(IND,1),AY(IND,1),AZ(IND,1)
        GOTO 20
C         ** PIPE DATA FOR OUTPUT
   56   CONTINUE
        IF(MAXCOL.LE.2) GOTO 75
        STPB(IND,I) = XI(1)/1.0E6
        STEN(IND,I) = XI(5)/1.0E6
        SBEN(IND,I) = XI(6)/1.0E6
        STOR(IND,I) = XI(7)/1.0E6
C          * PERFORM CALC. S WITH EASEZ DATA AND PRESSURE(P) DATA
        IP1 = ILOOP + 1
        GO TO (681,682,683,684,685),IND
  681   SPA(1,I) = 0.0
        SPT(1,I) = 0.0
        GOTO 686
  682   SPA(2,I) = 0.0
        SPT(2,I) = 0.0
        GOTO 686
  683   P(5,IP1) = P(5,IP1) - P(5,1)
        SPA(3,I) = 0.10*P(5,IP1)/R2M1(5)
        SPT(3,I) = 2*SPA(3,I)
        GOTO 686
  684   P(4,IP1) = P(4,IP1) - P(4,1)
        SPA(4,I) = 0.10*P(4,IP1)/R2M1(4)
        SPT(4,I) = 2*SPA(4,I)
        GOTO 686
  685   P(2,IP1) = P(2,IP1) - P(2,1)
        SPA(5,I) = 0.10*P(2,IP1)/R2M1(2)
        SPT(5,I) = 2*SPA(5,I)
  686   CONTINUE
C         (SPA AND SPT ARE THE AXIAL AND TANGENTIAL STRESS DUE TO
C         INTERNAL PRESSURE(P),RESPECTIVELY, THEY ARE AT INTERNAL
C         NODE POINTS(IND) 3,4,AND 5. UNITS OF STRESS ARE N/MM**2 .)
        J = IND
        SA(J,I) = STPB(J,I) + SPA(J,I)
        SV(J,I) = SQRT(SA(J,I)**2 + SPT(J,I)**2 - SA(J,I)*SPT(J,I)
      *                      + 3*STOR(J,I)**2)
C         (STPB,STEN,SBEN,STOR, ARE THE TENSILE + BENDING, TENSILE,
C         BENDING, AND TORSIONAL STRESSES, RESPECTIVELY, UNITS ARE
C         N/MM**2.)
C         (SV IS THE COMPARATIVE STRESS, UNITS ARE N/MM**2.)
```

```
      STAPE = 14 + IND
      WRITE(STAPE) STEN(IND,1),SBEN(IND,1),STOR(IND,1),SPT(IND,1),
     * SV(IND,1)
      GOTO 20
   75 CONTINUE
      MY(IND,I) = XI(1)
      MZ(IND,I) = XI(2)
      J = IND
      ZEROMO = 0.001
      MYY = ABS(MY(J,I))
      MZZ = ABS(MZ(J,I))
      MZZS = MZ(J,I)
      IF(MYY.LT.ZEROMO) GOTO 929
      ALPHA(J,I) = ATAN2(MZ(J,I),MY(J,I))*57.3
      GOTO 927
  929 CONTINUE
      IF(MZZ.LT.ZEROMO) GOTO 928
      IF(MZZS.GT.0.0) ALPHA(J,I) = 90.0
      IF(MZZS.LT.0.0) ALPHA(J,I) = -90.0
      GOTO 927
  928 CONTINUE
      ALPHA(J,I) = 0.0
  927 CONTINUE
C     (MY AND MZ ARE THE Y AND Z BENDING MOMENTS, UNITS ARE M*N.)
C     (ALPHA IS THE ANGLE OF THE BENDING AXIS, UNITS  ARE DEGREES.)
      ALTAPE = 19 + IND
      WRITE(ALTAPE) ALPHA(IND,1)
      GOTO 20
C     ** FORCE DATA FOR OUTPUT( F = TF*XI)
   57 CONTINUE
      FX(IND,I) =  TF(1,1,IND)*XI(1)  +  TF(1,2,IND)*XI(2)  +
     * TF(1,3,IND)*XI(3)
      FY(IND,I) = TF(2,1,IND)*XI(1)  +  TF(2,2,IND)*XI(2)  +
     * TF(2,3,IND)*XI(3)
      FZ( IND,I) = TF(3,1,IND)*XI(1)  +  TF(3,2,IND)*XI(2)  +
     * TF(3,3,IND)*XI(3)
C     (FORCE AT IND IS (FX,FY,FZ), UNITS ARE N.)
      FTAPE = 24 + IND
      WRITE(FTAPE) FX(IND,1),FY(IND,1),FZ(IND,1)
C
C      * IN THIS LOOP(10 TO 20) I = 1 .
C
   20 CONTINUE
      ISKIP = 1
C     ** TRANSFER TO -5- TO READ NEXT HEADER RECORD
      GOTO 5
 1000 CONTINUE
C
C     (ALL ITEMS HAVE BEEN CALCULATED.)
C
C      * REWIND TAPES 10 THRU 29
      DO 679 J=10,29
  679 REWIND J
C
C     ** WRITE OUT TO OUTPUT **
C
C      * FOR OUTPUT TO PRINTER VIA TAPE6 I = 1 .
      I = 1
      WRITE(6,307)
  307 FORMAT(1H1,43HOUTPUT CALC. RESULTS(OUTPUT EVERY ** STEPS),////)
      WRITE(6,331)
  331 FORMAT(1X,10HTIME ARRAY,//)
      K = 0
```

```
      DO 600 J=1,IDT
      READ(TTAPE) TTIME(1)
      K = K + 1
      IF(K.EQ.MB) GOTO 610
      GOTO 600
610   K = 0
      WRITE(6,332)  TTIME(I)
600   CONTINUE
332   FORMAT(3X,8E15.4)
      WRITE(6,333)
333   FORMAT(1H1)
      WRITE(6,308)
308   FORMAT(1X,13HDISPLACEMENTS,//)
      DO 310 IND=1,3
      WRITE(6,309) IND
309   FORMAT(1H ,6HIND = ,I5,/,8X,2HDX,14X,2HDY,14X,2HDZ,/)
      K = 0
      DTAPE = 10 + IND
      DO 641 J=1,IDT
      READ(DTAPE) DX(IND,1),DY(IND,1),DZ(IND,1)
      K = K + 1
      IF(K.EQ.M2) GOTO 611
      GOTO 641
611   K = 0
      WRITE(6,311)  DX(IND,I),DY(IND,I),DZ(IND,I)
641   CONTINUE
310   CONTINUE
311   FORMAT(    3(E12.4,4X))
      WRITE(6,312)
312   FORMAT(1H1,13HACCELERATIONS,//)
      WRITE(6,313)
313   FORMAT(1H ,7HIND = 1,/,8X,2HAX,14X,2HAY,14X,2HAZ,/)
      K = 0
      IND = 1
      ATAPE = 13 + IND
      DO 642 J=1,IDT
      READ(ATAPE) AX(IND,1),AY(IND,1),AZ(IND,1)
      K = K + 1
      IF(K.EQ.M2) GOTO 612
      GOTO 642
612   K = 0
      WRITE(6,311)  AX(1,I),AY(1,I),AZ(1,I)
642   CONTINUE
      WRITE(6,314)
314   FORMAT(1H1, 8HSTRESSES,//)
      DO 315 IND=1,5
      WRITE(6,316) IND
316   FORMAT(1H ,6HIND = ,I5,/,8X,4HSTEN,14X,4HSBEN,13X,5HALPHA,14X,
     *           4HSTOR,14X,3HSPT,14X,4H  SV,/ )
      K = 0
      STAPE = 14 + IND
      ALTAPE = 19 + IND
      DO 643 J=1,IDT
      READ(STAPE) STEN(IND,1),SBEN(IND,1),STOR(IND,1),SPT(IND,1),
     * SV(IND,1)
      READ(ALTAPE) ALPHA(IND,1)
      K = K + 1
      IF(K.EQ.M2) GOTO 613
      GOTO 643
613   K = 0
      WRITE(6,317)  STEN(IND,I),SBEN(IND,I),ALPHA(IND,I),STOR(IND,I),
     *              SPT(IND,I),SV(IND,I)
643   CONTINUE
```

```
  315 CONTINUE
  317 FORMAT(   6(E12.4,6X))
      WRITE(6,320)
  320 FORMAT(1H1, 6HFORCES,//)
      DO 321 IND=1,5
      WRITE(6,322) IND
  322 FORMAT(1H ,6HIND = ,I5,/,8X,2HFX,14X,2HFY,14X,2HFZ,/)
      K = 0
      FTAPE = 24 + IND
      DO 644 J=1,IDT
      READ(FTAPE) FX(IND,1),FY(IND,1),FZ(IND,1)
      K = K + 1
      IF(K.EQ.M2) GOTO 614
      GOTO 644
  614 K = 0
      WRITE(6,311)  FX(IND,I),FY(IND,I),FZ(IND,I)
  644 CONTINUE
  321 CONTINUE
C
C
C     ** OUTPUT DATA TO TAPE USING DOSYS FORMAT
C
C     * GENERATE DATA FOR FILE1 (DOSYS FORMAT)
      DO 698 J=10,29
  698 REWIND J
      TIMSTP = 0.0002
      NTRAN = 42
      ICHAN = 30
      DO 833 J=1,42
  833 IW4(J) = J
      IDATE = 6H810327
      CALL DOSYSW(TTIME,TIMSTP,NTRAN,IDT,XOUT,42,ICHAN,IW4,IDATE,0)
C      * SET I = 1 FOR GEN. GERMAN OUTPUT.
      I = 1
      DO 500 ILOOP = 1,IDT
      READ(TTAPE) TTIME(1)
      DO 400 IND=1,3
      DTAPE = 10 + IND
  400 READ(DTAPE) DX(IND,1),DY(IND,1),DZ(IND,1)
      IND = 1
      ATAPE = 13 + IND
      READ(ATAPE) AX(IND,1),AY(IND,1),AZ(IND,1)
      DO 401 IND=1,5
      STAPE = 14 + IND
  401 READ(STAPE) STEN(IND,1),SBEN(IND,1),STOR(IND,1),SPT(IND,1),
     * SV(IND,1)
      DO 402 IND=1,5
      ALTAPE = 19 + IND
  402 READ(ALTAPE) ALPHA(IND,1)
      TTIME(1) = TTIME(1) - 0.0966
      XOUT(I, 1) = DY(1,I)
      XOUT(I, 2) = DX(1,I)
      XOUT(I, 3) = DZ(1,I)
      XOUT(I, 4) = DY(2,I)
      XOUT(I, 5) = DZ(2,I)
      XOUT(I, 6) = DX(2,I)
      XOUT(I, 7) = DZ(3,I)
      XOUT(I, 8) = DX(3,I)
      XOUT(I, 9) = DY(3,I)
      XOUT(I,10) = AX(1,I)
      XOUT(I,11) = AY(1,I)
      XOUT(I,12) = AZ(1,I)
      XOUT(I,13) = STEN(1,I)
```

```
      XOUT(I,14) = SBEN(1,I)
      XOUT(I,15) = ALPHA(1,I)
      XOUT(I,16) = STOR(1,I)
      XOUT(I,17) = 0.0
      XOUT(I,18) = 0.0
      XOUT(I,19) = STEN(2,I)
      XOUT(I,20) = SBEN(2,I)
      XOUT(I,21) = ALPHA(2,I)
      XOUT(I,22) = STOR(2,I)
      XOUT(I,23) = 0.0
      XOUT(I,24) = 0.0
      XOUT(I,25) = STEN(3,I)
      XOUT(I,26) = SBEN(3,I)
      XOUT(I,27) = ALPHA(3,I)
      XOUT(I,28) = STOR(3,I)
      XOUT(I,29) = SPT(3,I)
      XOUT(I,30) = SV(3,I)
      XOUT(I,31) = STEN(4,I)
      XOUT(I,32) = SBEN(4,I)
      XOUT(I,33) = ALPHA(4,I)
      XOUT(I,34) = STOR(4,I)
      XOUT(I,35) = SPT(4,I)
      XOUT(I,36) = SV(4,I)
      XOUT(I,37) = STEN(5,I)
      XOUT(I,38) = SBEN(5,I)
      XOUT(I,39) = ALPHA(5,I)
      XOUT(I,40) = STOR(5,I)
      XOUT(I,41) = SPT(5,I)
      XOUT(I,42) = SV(5,I)
      CALL DOSYSW(TTIME,TIMSTP,NTRAN,1,XOUT,42,ICHAN,IWH, IDATE,1)
  500 CONTINUE
C
C     * GENERATE DATA FOR FILEZ (DOSYS FORMAT)
C
      REWIND 10
      NTRAN = 15
      ICHAN = 31
      CALL DOSYSW(TTIME,TIMSTP,NTRAN,IDT,XOUT,42,ICHAN,IWH,IDATE,0)
C     * SET I = 1 FOR OUTPUT OF FORCES.
      I = 1
      DO 595 ILOOP=1,IDT
      READ(TTAPE) TTIME(1)
      DO 530 IND=1,5
      FTAPE = 24 + IND
  530 READ(FTAPE) FX(IND,1),FY(IND,1),FZ(IND,1)
      TTIME(1) = TTIME(1) - 0.0966
      XOUT(I, 1) = FX(1,I)
      XOUT(I, 2) = FY(1,I)
      XOUT(I, 3) = FZ(1,I)
      XOUT(I, 4) = FX(2,I)
      XOUT(I, 5) = FY(2,I)
      XOUT(I, 6) = FZ(2,I)
      XOUT(I, 7) = FX(3,I)
      XOUT(I, 8) = FY(3,I)
      XOUT(I, 9) = FZ(3,I)
      XOUT(I,10) = FX(4,I)
      XOUT(I,11) = FY(4,I)
      XOUT(I,12) = FZ(4,I)
      XOUT(I,13) = FX(5,I)
      XOUT(I,14) = FY(5,I)
      XOUT(I,15) = FZ(5,I)
      CALL DOSYSW(TTIME,TIMSTP,NTRAN,1,XOUT,42,ICHAN,IWH, IDATE,1)
  595 CONTINUE
```

```
      ENDFILE 30
      ENDFILE 30
      ENDFILE 31
      ENDFILE 31
      STOP
      END
```

```
C*******************************************************************
C
      SUBROUTINE DOSYSW(STRTIM,TIMSTP,NTRAN,NPTS,TDATA,MAXTRN,ICHAN,
     *                  IWHERE,IDATE,IFLAG)
C
C*******************************************************************
C
C     PURPOSE THIS ROUTINE IS USED TO OUTPUT DATA TO DOSYS FORMAT
C             TAPES.
C     NOTE    THE FORMAT STATEMENTS IN THIS ROUTINE ARE SPECIFIC TO
C             THE NSF PROJECT 1182.08.
C
C     INPUTS  STRTIM START TIME OF THE DATA
C             TIMSTP DELTA TIME FOR EACH STEP
C             NTRAN  NUMBER OF TRANSDUCERS(CHANNELS OF DATA)
C             NPTS   NUMBER OF TIME POINTS
C             TDATA  TRANSDUCER DATA
C             MAXTRN MAXIMUM TRANSDUCERS, USED IN DIMENSIONING TDATA
C             ICHAN  CHANNEL NUMBER OF DOSYS TAPE
C             IWHERE INDICATES WHICH SETS OF TDATA ARE USED AS WHICH
C                    TRANSDUCERS. A 0 INDICATES THAT ZEROES ARE TO
C                    BE OUTPUT FOR THAT CHANNEL.
C             IDATE  INTEGER DATE(I.E. FEB 3,1681 = 810203)
C             IFLAG  IF.LT.0 OUTPUT HEADER AND DATA
C                    IF.EQ./ OUTPUT  HEADER ONLY
C                    IF.GT./ OUTPUT DATA ONLY
C
C     OUTPUTS ALL OUTPUT IS TO THE DOSYS TAPE OR THE LISTING FILE(6).
C
C*******************************************************************
C
C     MOD     DATE    BY       REASON
C     1.0     3/81    LJS      ORIGINAL
C
C*******************************************************************
C
      DIMENSION TDATA(NPTS,MAXTRN),IWHERE(NTRAN),OUTDAT(256)
C
C     CHECK FOR WHETHER TO OUTPUT HEADER OF NOT
C
      IF(IFLAG) 50,50,210
   50 CONTINUE
C
C     WRITE OUT HEADER
C
      WRITE(ICHAN,9000) IDATE,IDATE,NTRAN,NPTS
      IF(NTRAN.NE.42) GOTO 100
C
C     IF 42 CHANNELS, MUST BE THE TRANSDUCER INFORMATION
C
      WRITE(ICHAN,9001)
      WRITE(ICHAN,9101)
      WRITE(ICHAN,9201)
      WRITE(ICHAN,9301)
      WRITE(ICHAN,9401)
      WRITE(ICHAN,9501)
      WRITE(ICHAN,9601)
      GOTO 200
C
C     IF OTHER THAN 42, MUST BE FORCES.
C
  100 CONTINUE
      N=NTRAN
```

```
      IF(N.GT.9) N=9
      DO 120 I=1,N
        WRITE(ICHAN,9002) I
  120 CONTINUE
      IF(NTRAN.LT.10) GOTO 200
      N = NTRAN
      IF(N.GT.99) N = 99
      DO 130  I = 10,N
        WRITE(ICHAN,9003) I
  130 CONTINUE
      IF (NTRAN.LT.100) GO TO 200
      DO 140  I = 100,NTRAN
        WRITE(ICHAN,9004) I
  140 CONTINUE
  200 CONTINUE
      IF(IFLAG.EQ.0) RETURN
C
C     OUTPUT DATA POINTS
C
  210 CONTINUE
      TIME = STRTIM
      DO 400 I = 1,NPTS
        DO 300  J = 1,NTRAN
          IF(IWHERE(J).EQ.0) GOTO 250
          OUTDAT(J) = TDATA(IWHERE(J),I)
          GOTO 300
  250     CONTINUE
          OUTDAT(J) = 0.0
  300   CONTINUE
        WRITE(ICHAN,9005)  TIME,(OUTDAT(J),J=1,NTRAN)
  400 CONTINUE
      RETURN
C
C     FORMATS
C
 9000 FORMAT(A6/6HEV3000,/5HV60.4,/4HCANC,/A6,/,
     +        13HSP4AHDRSRV350///////////I5/I5)
 9001 FORMAT( 10HRS2201  MM,19X,3HL02,10X,6H003400,/
     +         17HWEG IN Y-RICHTUNG,/
     +          10HRS2202  MM,19X,3HL02,10X,6H003400,/
     +         17HWEG IN X-RICHTUNG,/
     +          10HRS2203  MM,19X,3HL02,10X,6H003400,/
     +         17HWEG IN Z-RICHTUNG,/
     +          10HRS2204  MM,19X,3HL02,10X,6H003400,/
     +         17HWEG IN Y-RICHTUNG,/
     +          10HRS2205  MM,19X,3HL02,10X,6H003400,/
     +         17HWEG IN Z-RICHTUNG,/
     +          10HRS2206  MM,19X,3HL02,10X,6H003400,/
     +         17HWEG IN X-RICHTUNG)
 9101 FORMAT( 10HSS4004  MM,19X,3HARS,10X,6H000000,/
     +         17HWEG IN Z-RICHTUNG,/
     +          10HSS4005  MM,19X,3HARS,10X,6H000000,/
     +         17HWEG IN X-RICHTUNG,/
     +          10HSS4006  MM,19X,3HARS,10X,6H000000,/
     +         17HWEG IN Y-RICHTUNG,/
     +          10HSS4001  G ,19X,3HARS,10X,6H  -250,/
     +         28HBESCHLEUNIGUNG IN X-RICHTUNG,/
     +          10HSS4002  G ,19X,3HARS,10X,6H  -250,/
     +         28HBESCHLEUNIGUNG IN Y-RICHTUNG,/
     +          10HSS4003  G ,19X,3HARS,10X,6H  -250,/
     +         28HBESCHLEUNIGUNG IN Z-RICHTUNG)
 9201 FORMAT( 13HRK1010  N/MM2,/
     +         11HZUGSPANNUNG,/
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     *           13HRK2010  N/MM2,/
     *          13HBIEGESPANNUNG,/
     *           12HRK2210  GRAD ,/
     *          21HWINKEL DER BIEGEACHSE,/
     *           13HRK3010  N/MM2,/
     *          16HTORSIONSSPANNUNG,/
     *           13HRK4110  N/MM2,/
     *          35HTANGENTIALSPANNUNG DURCH INNENDRUCK,/
     *           13HRK5010  N/MM2,/
     *          18HVERGLEICHSSPANNUNG)
 9301  FORMAT( 13HRK1011  N/MM2,/
     *          11HZUGSPANNUNG,/
     *           13HRK2011  N/MM2,/
     *          13HBIEGESPANNUNG,/
     *           12HRK2211  GRAD ,/
     *          21HWINKEL DER BIEGEACHSE,/
     *           13HRK3011  N/MM2,/
     *          16HTORSIONSSPANNUNG,/
     *           13HRK4111  N/MM2,/
     *          35HTANGENTIALSPANNUNG DURCH INNENDRUCK,/
     *           13HRK5011  N/MM2,/
     *          18HVERGLEICHSSPANNUNG)
 9401  FORMAT( 13HRK1012  N/MM2,/
     *          11HZUGSPANNUNG,/
     *           13HRK2012  N/MM2,/
     *          13HBIEGESPANNUNG,/
     *           12HRK2212  GRAD ,/
     *          21HWINKEL DER BIEGEACHSE,/
     *           13HRK3012  N/MM2,/
     *          16HTORSIONSSPANNUNG,/
     *           13HRK4112  N/MM2,/
     *          35HTANGENTIALSPANNUNG DURCH INNENDRUCK,/
     *           13HRK5012  N/MM2,/
     *          18HVERGLEICHSSPANNUNG)
 9501  FORMAT( 13HRK1013  N/MM2,/
     *          11HZUGSPANNUNG,/
     *           13HRK2013  N/MM2,/
     *          13HBIEGESPANNUNG,/
     *           13HRK2213  N/MM2,/
     *          21HWINKEL DER BIEGEACHSE,/
     *           13HRK3013  N/MM2,/
     *          16HTORSIONSSPANNUNG,/
     *           13HRK4113  N/MM2,/
     *          35HTANGENTIALSPANNUNG DURCH INNENDRUCK,/
     *           13HRK5013  N/MM2,/
     *          18HVERGLEICHSSPANNUNG)
 9601  FORMAT( 13HRK1014  N/MM2,/
     *          11HZUGSPANNUNG,/
     *           13HRK2014  N/MM2,/
     *          13HBIEGESPANNUNG,/
     *           13HRK2214  N/MM2,/
     *          21HWINKEL DER BIEGEACHSE,/
     *           13HRK3014  N/MM2,/
     *          16HTORSIONSSPANNUNG,/
     *           13HRK4114  N/MM2,/
     *          35HTANGENTIALSPANNUNG DURCH INNENDRUCK,/
     *           13HRK5014  N/MM2,/
     *          18HVERGLEICHSSPANNUNG)
 9002 FORMAT( 5HRF000,I1,3H  N,19X,3HL02,10X,6H......,/)
 9003 FORMAT( 4HRF00, I2,3H  N,19X,3HL02,10X,6H......,/)
 9004 FORMAT( 3HRF0,  I3,3H  N,19X,3HL02,10X,6H......,/)
 9005 FORMAT(6E12.5,8X)
      END
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This study deals with structural piping response to dynamic loads generated by hydraulic transients in nuclear power plants. Transients were induced by means of a rupture disc and closure of a feedwater check valve at the Heissdampfreaktor, West Germany. Blind predictions of piping response were made using the computer code EASE2. Comparison between computer simulations and experimental observations are contained in the report.

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